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ARTICULATED HIGHWAY BUS DEMONSTRATION

PREPARED FOR
TRANSPORT CANADA
TRANSPORTATION DEVELOPMENT CENTRE
BY
VOYAGEUR ENTERPRISES LTD.

PTEMBER 1984

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Prepared for

Transport Canada

Transportation Development Centre

by

Voyageur Enterprises Ltd.

September, 1984

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17. Abstract

In order to assess the financial and oper onal feasibility of using larger intercity bus equipment in Canada, a revenue servic emonstration of an existing articulated bus was undertaken. After a comprehensiv eview of the currently available products, a Neoplan 120N/4 was selected, modified a elivered in February 1980.

The study indicated that from an infrastr re and operation view point, an articulated bus could be accommodated within t rrent operating environment. The results of the initial "shakedown" and the revent rvice experience identified many product-specific and durability problems. As a r t of these problems and specifically due to the structural failure of the articula joint, the revenue service demonstration was prematurally cancelled in January 198 Because of the abnormally poor performance of the particular product tested, n neralized economic feasibility conclusion with regard to articulated highway coache n be made.

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17. Résumé

Ce rapport rend compte des résultats de l'exploitation expérimentale en service payant d'un autocar articulé de production courante. L'essai avait été décidé pour connaître l'intérêt économique et technique de mettre en service des autocars de grande capacité au Canada et portait sur un véhicule articulé de marque Neoplan 120N/4 livré après modifications en février 1980. Celui-ci avait été choisi après un examen exhaustif de tous les modèles disponibles.

Les conclusions de l'étude sont que les infrastructures et les méthodes d'exploitation actuelles autorisent la mise en service d'un autobus articulé au Canada. Par contre, les essais préliminaires et l'exploitation en service payant ont mis en évidence un nombre important de problèmes propres au véhicule testé et aussi de durabilité. Le nombre des problèmes constatés et, plus particulièrement, la rupture de l'articulation ont forcé Voyageur Inc. à mettre fin à l'expérience plutôt que prévu, c'est-à-dire dès janvier 1983. La tenue anormalement médiocre du véhicule testé a fait qu'aucune généralisation n'a été possible quant à l'intérêt économique des autocars articulés au Canada.

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Autocar articulé, autobus grande capacité, Canada.	Le CDT dispose d'un nombre limité d'exemplaires.

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1.0 INTRODUCTION

1.1 PROJECT DEVELOPMENT

This demonstration project was undertaken as a direct result of the findings of a Transport Canada sponsored study which investigated the economics of using larger buses in intercity service.[1] This analytical study used Voyageur Enterprises Ltd. (Voyageur) as a test operator for the analysis and resulted in estimates of cost reductions accessible through the introduction of higher capacity buses as shown in Table 1.1. These results were of sufficient interest to Voyageur that it proposed a joint venture demonstration of an articulated bus with Transport Canada's assistance.

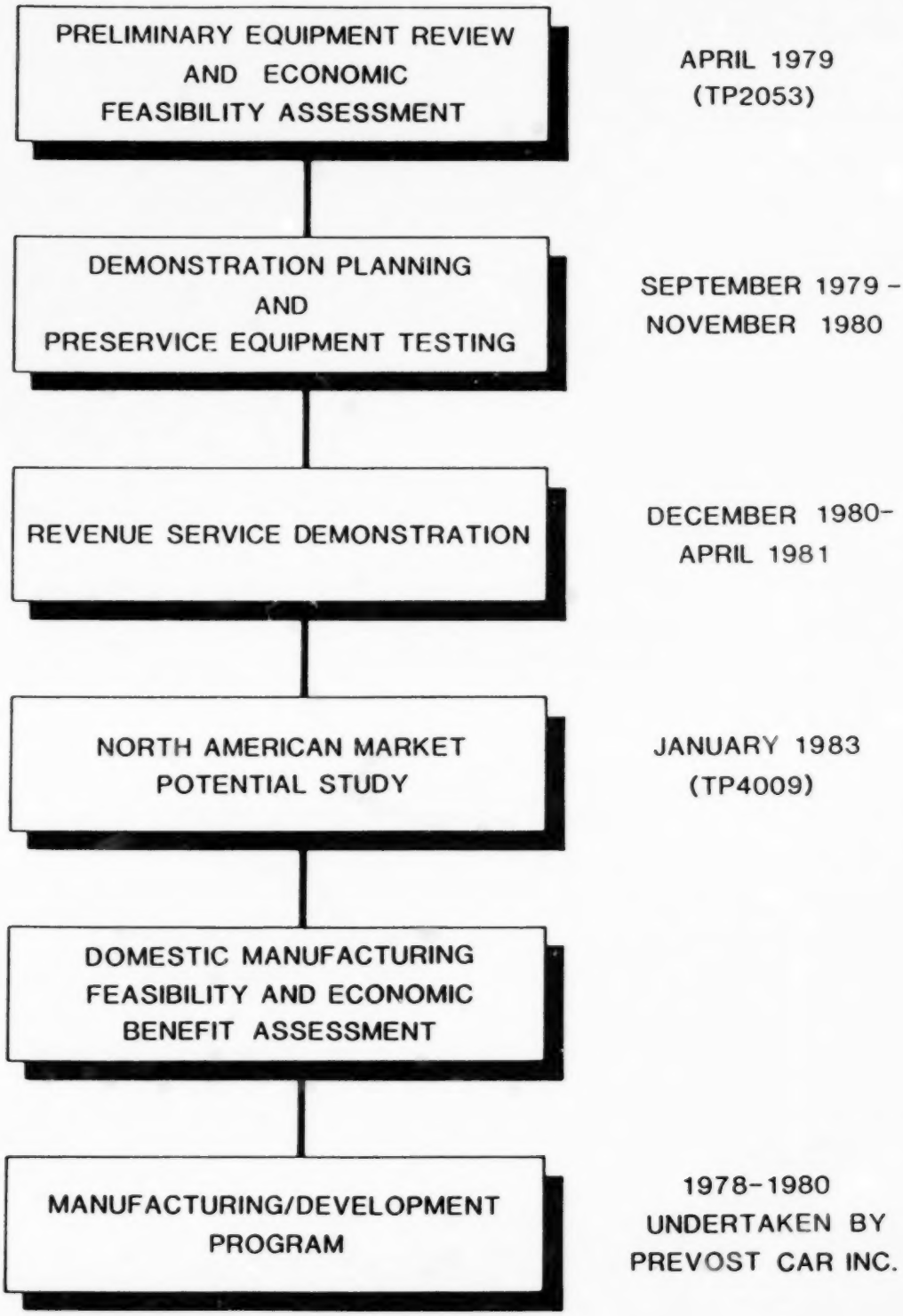
TABLE 1.1: RANGE OF COST REDUCTION BY TYPE OF HIGH CAPACITY BUS (% reduction)

Origin/Destination	Double-Deck (69 or 81 seats)	Articulated (77 or 81 seats)	Jumbo (91 or 103 seats)
Ott-Tor	5.4 - 10.2	6.4 - 8.7	6.5 - 8.5
Tor-Ott	6.2 - 11.0	5.7 - 9.5	7.0 - 9.0
Mtl-Tor	5.1 - 7.2	5.8 - 16.8	2.3 - 2.8
Tor-Mtl	9.8 - 15.0	9.3 - 13.2	8.2 - 10.6
Mtl-Ott	13.0 - 19.1	12.8 - 17.4	12.2 - 14.0
Ott-Mtl	14.2 - 21.0	14.1 - 17.0	15.7 - 17.9
Mtl-QC	12.5 - 18.7	12.2 - 17.0	12.5 - 14.4
QC-Mtl	12.8 - 18.7	11.5 - 17.0	13.2 - 16.2

The overall research and development program proposed to Transportation Development Centre is shown in Figure 1.1. This plan presented a logical series of demonstration and analyses which would ultimately result in the manufacturing of larger buses in Canada.

1. N.D. Lea & Associates Ltd., "A Feasibility Study on the Introduction of Larger Capacity Intercity Buses" (April 1979, Transport Canada, TP2053).

FIGURE 1.1 PROPOSED R&D PROGRAM


PRELIMINARY EQUIPMENT REVIEW AND ECONOMIC FEASIBILITY ASSESSMENT
APRIL 1979 (TP2053)
DEMONSTRATION PLANNING AND PRESERVICE EQUIPMENT TESTING
SEPTEMBER 1979 - NOVEMBER 1980
REVENUE SERVICE DEMONSTRATION
DECEMBER 1980- APRIL 1981
NORTH AMERICAN MARKET POTENTIAL STUDY
JANUARY 1983 (TP4009)
DOMESTIC MANUFACTURING FEASIBILITY AND ECONOMIC BENEFIT ASSESSMENT
MANUFACTURING/DEVELOPMENT PROGRAM
1978-1980 UNDERTAKEN BY PREVOST CAR INC.

The proposed demonstration was intended to validate the cost savings and operating feasibility of the feasibility report. To do this, existing European-design coaches were to be acquired and run for a period of time on Voyageur routes while detailed cost reporting, reliability and passenger opinion information was obtained. On the basis of this demonstration, there would then be an evaluation of whether this concept was workable on North American routes.[1]

The overall program for the evaluation of higher capacity buses was proposed in the following steps:

- revenue service demonstration of existing equipment of which the single deck articulated was but one option;
- a analysis of the potential markets for higher capacity coaches in North America;
- at this point a decision would be made as to the further funding of the development on intercity coaches made in Canada;
- a target manufacturer would be selected and supported for the development of a prototype coach.

This program sequence was not maintained as Prevost Car Inc. proposed and was given a Enterprise Development Program grant to develop an articulated intercity coach shortly after Voyageur's proposal. Thus, a development decision was made well in advance of either the revenue service demonstration experience or the full market study.

As a result of the Voyageur proposal, a contract between Transport Canada and Voyageur Enterprises Ltd. was negotiated and signed in September, 1979.

1.2 PROJECT PLAN

The primary objective of this study was to develop information to assist intercity operators in assessing the potential deployment of articulated intercity buses on selected intercity routes. As such, the demonstration attempted to assess the articulated intercity bus in terms of operational, service and maintenance characteristics, and impacts on operating costs and passenger level of service.

The study was designed to evaluate the issues that would be of interest to intercity operators. These issues can be grouped into three broad categories, namely:

- operational and service characteristics;
- maintenance experience;
- economic analysis.

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1. James F. Hickling Management Consultants Ltd., "Intercity Bus Design-A Route to the Future", January, 1983, Transport Canada, TP4009.

The program of work was broken down into the following milestone events.

1. Program Organization and Pre-Planning
2. Equipment Procurement
3. Infrastructure Study and Modifications
4. Pre-introduction Survey
5. Marketing Plan
6. Demonstration Operational Plan
7. Data Collection System Design
8. Implementation and Testing of Data Collection System
9. Acceptance of First Vehicle in Montreal
10. Vehicle Roadtesting of the First Unit
11. Instrumentation and Further Testing on the First Unit
12. Acceptance of the Last Four Units
13. Road-testing of the Last Four Units
14. Final Report Generation

Fortunately, the program of work was considered to be flexible subject to the availability and successes attained in each milestone. Thus, when the project did encounter significant problems with the NEOPLAN articulated bus, it was decided that a total of 5 articulated buses from NEOPLAN would not be procurred and tested as required under the project agreement. The program of work was therefore altered mid-way through the project, such that Task 12 (Acceptance of the Last Four Units) and Task 13 (Road-testing of the Last Four Units) were deleted from the project. Tasks 12 and 13 were replaced with the following:

12. Training Program for Drivers
13. Data Evaluation from the Revenue Service Trial

The project schedule is shown in Figure 1.2 and indicates the original and achieved schedule of events. As will be noticed, significant program time slippage occurred due to equipment mechanical problems. The revenue service actually commenced on December 4, 1981 and continued until mid January, 1982 when major structure failures occurred. The demonstration was subsequently cancelled and the bus eventually sold in January 1983 to Murray Hill Bus Lines (Montreal) in January 1983 for city tour bus service.

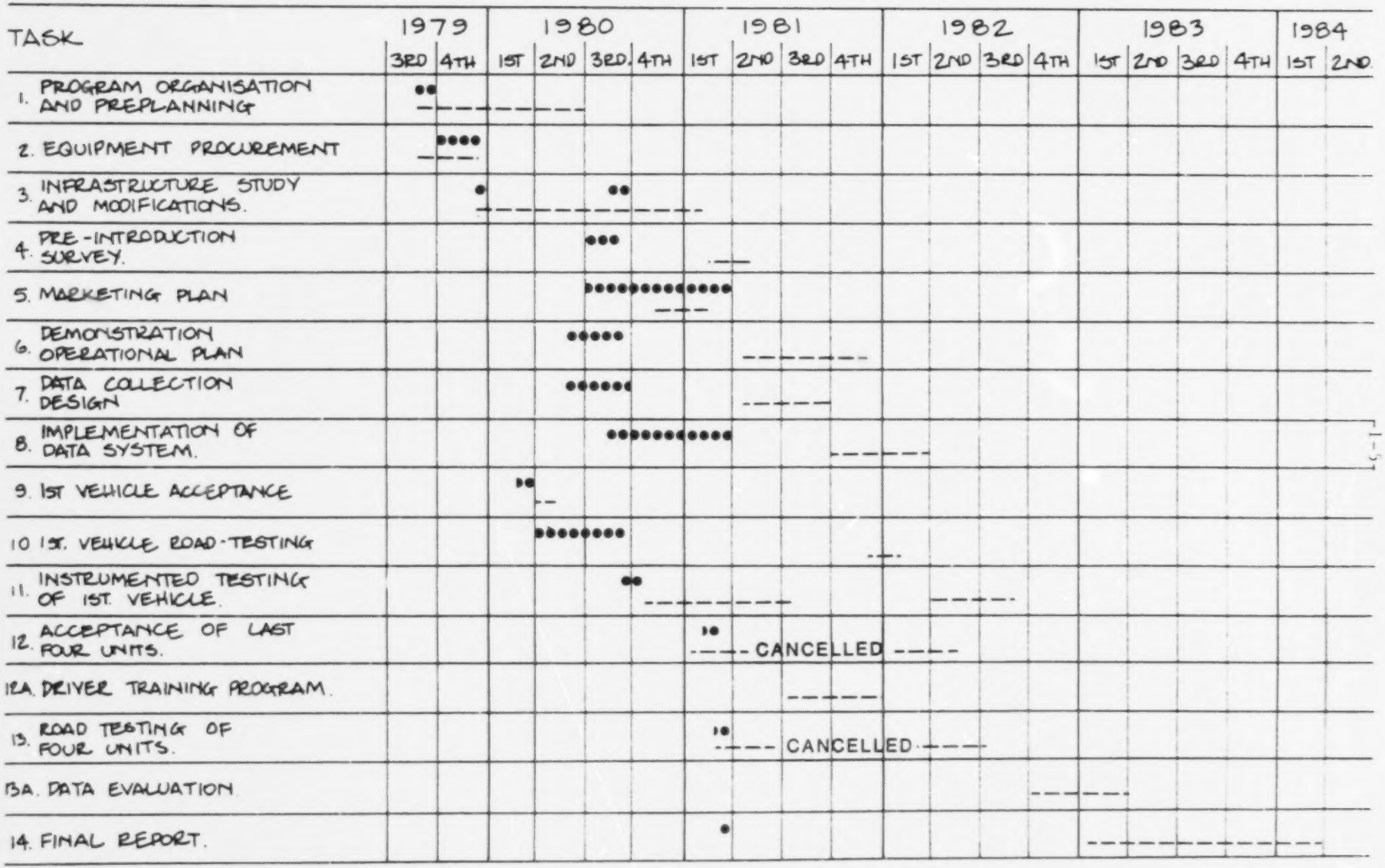
1.3 VEHICLE SELECTION

Once the development program had been designed, a detailed review and assessment of the European products was required:

- to validate to the satisfaction of Voyageur the technical and operating acceptability of the buses identified;
- to investigate the capability of each manufacturer to modify their buses to conform with the performance specifications of a North American manufactured bus.

Senior members of Voyageur and a Transport Canada representative attended the 1979 Annual International Bus Show in Belgium and visited the factories of potential suppliers of higher capacity intercity buses.

FIGURE 1.2 ARTICULATED BUS PROJECT SCHEDULE



Prior to the European visits, Voyageur assessed the relative merits of three styles of buses. It was concluded that, based on its ability to integrate the new buses into existing operations, Voyageur would rank them in the following order of preference:

1) Articulated Single-Deck Bus

- minimizes need for infrastructure change;

2) Double-Deck Bus

- requires substantial infrastructure changes;
- could present operational problems requiring a second person for control of the upper deck;

3) Double-Deck Articulated Bus

- has all the disadvantages of the double-deck added to the fact that Voyageur has no experience with articulated vehicles.

Discussions with three manufacturers (Gottlob-Auwarter GMBA (NEOPLAN), VAN HOOL and Walter Vetter Karosseriewerk) and on-site observations and ranking were performed during the European visit (see Table 1.2). It was concluded that prior reservations about the double-deck bus were well founded for the following reasons:

- control of the upper deck by the driver would be impossible;
- seating capacity would be reduced to obtain acceptable baggage capacity;
- the height of the upper deck was such that an individual would have difficulty walking upright - a problem which would in all likelihood make this type of bus illegal in North America.

The Neoplan single-deck articulated bus was evaluated as the only unit which, with some modification, would be acceptable within the Voyageur system and in the North American context. It was therefore recommended that one Neoplan articulated bus be purchased as a test model. Although there were problems associated with the use of European equipment, it was felt that the experiment could proceed for two reasons:

- risk could be minimized with the incorporation, where feasible, of North American components;
- North American manufacturers had no similar pieces of equipment.

TABLE 1.2: SUMMARY OF COMPARATIVE EVALUATION OF ARTICULATED BUSES

ITEM	VETTER	VAN HOOL	NEOPLAN
Assessment of Manufacturer	• Custom builder, no mass production experience • No after sales service of export market	• Same as Vetter	• Mass producers with the capability to customize coaches • Existing export sales/support organization
Conclusion	• Bus would require extensive modifications, with which the manufacturer has little experience. • Technical support after sale appears questionable • Rejected	• Same as Vetter	• Neoplan has some experience in making the required modifications. They have an existing export sales force and "trouble-shooting" team for the export market. The company is keen on penetrating the North American market.

The vehicle was specified to have the following special equipment:

- Detroit Diesel 8V-92TA engine,
- Allison HT754CR transmission with retarder,
- push-out double-glazed windows,
- insulated roof-hatches,
- air conditioning,
- opening drivers window,
- vapour barrier in sidewall,
- radiator shutters,
- 24V sealed beam head lamps.

The vehicle was delivered in February, 1980, at the Port of Montreal (Figure 1.2) and was immediately put into an acceptance testing program. A comparison of the NEOPLAN with a MC-9 (standard Voyageur coach) is presented in Table 1.3.

TABLE 1.3: COMPARISON OF NEOPLAN VS MCI COACHES

CHARACTERISTIC	NEOPLAN	MCI
Model	N120	MC-9
Capacity	61	43
Length	18 m./59 ft.	12.2 m./40 ft.
Width	2.49 m./98 in.	2.44 m./96 in.
Height	3.56 m./140 in.	3.38 m./133 in.
Weight	22.226 kg./49,000 lbs.	12,247 kg./27,000 lbs.
Engine	287 kw./385 HP	213 kw./285 HP
Transmission	5 gears	4 gears
Turning Radius	12.2 m./40 ft.	15.24 m./50 ft.
Max. Speed	100 km/h	112 km/h

FIGURE 1.3 NEOPLAN ARRIVAL IN MONTREAL

2.0 PRE-DEMONSTRATION TESTING AND PREPARATION

2.1 REGULATORY ACCEPTANCE

As originally manufactured the Neoplan articulated bus did not conform to Canadian Highway Regulations in two respects. Its length was 18.3 metres versus the allowable maximum of 12.2 metres, and some of the sub-systems, namely brakes, did not conform to North America standards. However, Federal and Provincial Authorities indicated that subject to confirmation of the suitability of the NEOPLAN braking system and high speed maneuverability, a temporary permit could be issued to allow operation of the articulated intercity bus on a service demonstation.

Voyageur carried out the necessary braking tests at the Transport Canada Motor Vehicle Test Facility in May of 1980. The tests results showed that the NEOPLAN braking performance exceeded federal specification and were fully satisfactory (Table 2.1). However, the NEOPLAN exhibited some lateral instability during the high speed lane changing trials. Since the observed instability (lateral sway) compared favourably with that observed for conventional 12.2 metre buses, the NEOPLAN was judged to be fully acceptable for use on Canadian highways.

TABLE 2.1: BRAKING TEST RESULTS

NOMINAL SPEED (kw/h)	EXACT SPEED (kw/h)	ACTUAL STOPPING DISTANCE(m)	CORRECTED STOPPING DISTANCE(m)	FMVSS21 STANDARD
Dry Pavement				
32	33.2	55.7	52.3	56.3
48	49.6	96.6	90.9	120.7
64	64.7	175.6	173.8	210.8
80	81.6	243.2	235.9	326.7
97	93.2	323.5	346.3	471.5
Wet Pavement				
32	32.0	46.2	50.2	96.6
48	65.2	292.1	283.4	--

The temporary permits were granted by the Federal and Provincial authorities and the vehicle was ready for continuation of the pre-demonstration performance trials and introduction into regular service.

2.2 COMPARATIVE PERFORMANCE TESTING

In order to assess the NEOPLAN coach's performance on winter road conditions, a test program was carried out at Transport Canada's Motor Vehicle Test Centre in the winter of 1980. To properly evaluate the bus' performance, it was compared with a standard MC-9 bus drawn from the Voyageur fleet.

The purpose of the test program was to acquire valid comparative data on road characteristics and stability under winter conditions. The following testing was performed on both buses:

- braking test on straight and level
- braking while cornering test
- pulling ability test
- lane change test
- cornering test
- trial test.

These various tests were performed on four different surfaces, whenever possible, and for two loading conditions.

ROAD SURFACES	EMPTY BUS	RATED GVW
compacted snow	•	•
fresh snow	•	•
dry ice	•	•
wet ice	•	•

2.2.1 Experimental Control

In order to ensure consistent and repeatable test results, the test procedures attempted to control the following variables:

- the condition of the road surface,
- the condition of the tires,
- the experience of the drivers.

The effect of surface conditions varying with time was reduced by alternating the test order of the two buses. In this manner, variations due to temperature change or polishing of the surfaces were greatly reduced. Tire type was standardized and tread-wear checked for equality to cancel out any tire traction advantages.

Drivers were switched from one bus to the other so that data could be obtained for each driver under all conditions.

Finally, due to the wide variations expected from test run to test run, it was decided to repeat the runs 10 to 15 times in order to be able to apply statistical analysis to the data.

2.2.2 Test Procedures

The following test procedures were used for each of the loading and surface conditions.

Braking Test

Braking test shows the ability of vehicle to stop in a straight line on a level surface. Thus, stopping distance from initial speed and vehicle stability were measured. Due to the low friction coefficient of the test surfaces, an initial speed of 48 km/h was chosen, giving stopping distances long enough to be discriminatory.

The test procedure consisted of:

a. Accelerate in a straight line to a speed of 35 km/hr;

b. With the vehicle in neutral gear, allow the vehicle speed to decrease by 5 km/hr;

c. Apply the brakes with sufficient force in order to lock all wheels at the same time;

d. Apply the same force until the vehicle has been brought to a full stop;

e. Record initial speed and braking distance from 5th wheel;

f. Record any deviation of the vehicle from its traffic lane.

Static Traction Test

The static pulling test is a measure of the ability of a vehicle to start, from standstill, while a load is opposing the motion. This load can be due to a grade, fresh snow or a combination of the two. To measure the static pulling ability, the following procedure was employed:

a. Using chains, tie rear of test vehicle to a stationnary vehicle;

b. Install the load cell in the chain;

c. With the vehicle in gear, accelerate slowly until wheels start spinning;

d. Record maximum reading of load cell prior to wheel spin.

Dynamic Traction Test

The dynamic pulling ability test is a measure of the ability of a vehicle to drive while a load is opposing the motion. To measure the dynamic pulling ability the vehicle is driven at a very low speed and a traction load is measured at various degrees of wheel slip using the following steps:

a. Using chains, tie rear of test vehicle to another vehicle;

b. Install the load cell in the chain;

c. With the test vehicle in gear, accelerate in order to reach a speed of 4 km/h without any wheel spin and record the load at 0% slip;

d. While braking the other vehicle, accelerate the test vehicle in order to maintain the speed of 4 km/h while inducing a 100% wheel slip at the drive axle (wheel speed equal to 8 km/hr) and record the load cell reading;

e. Repeat above procedure with a 200% wheel slip;

f. Repeat above procedure with a 300% wheel slip.

Cornering Test

The objective of this test is to measure the lateral acceleration that can be produced by the vehicle while cornering at a constant rate. This value is affected by the vehicle characteristics and will give an indication of the maximum speed at which a given turn can be negotiated. The stability of the vehicle is also observed during the steps below:

a. Mark a 46 m radius circle, with a 3.7 m wide lane;

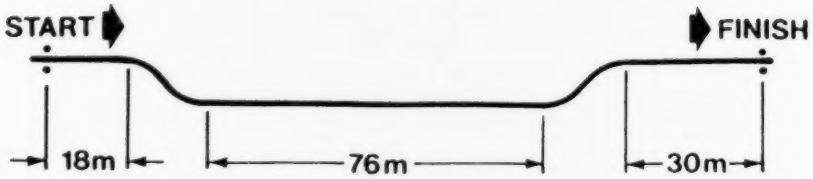
b. Accelerate the vehicle in order to reach the highest constant speed around a full circle;

c. Record time to drive one full circle, distance driven and speed.

Lane Change Test

The objective of the lane change test is to measure the stability of the vehicle in a transient state. Time required to complete the course is measured in order to compute the average speed on the course. Speeds at beginning and end of the course are also noted in order to check the steadiness of the speed through the course. Vehicle stability is also checked during the following sequence.

a. Delimit a course as shown below:



LANE CHANGE TEST

b. By trials, find the highest constant speed that can be maintained through the course;

c. Bring the vehicle to the speed as determined above at the beginning of the course;

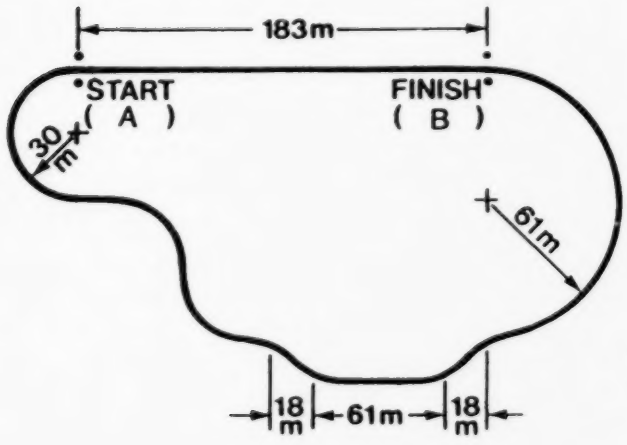
d. Drive through the course while trying to maintain the same speed;

e. Record time elapsed, distance through the course and speed at beginning and end of course.

Test Drive Course

The objective of this test is to measure the stability and overall performance on a short course. Thus, the test is a combination of previous tests and gives an overall view of the vehicles under various conditions. Time for the course was measured in order to compute an average speed. The test procedure was as follows:

a. Mark a course as shown below:



TRIAL TEST ROUTE

b. From a standing start at point "A", drive through the course as fast as possible;

c. Come to a full stop with front of vehicle at point "B";

d. Record time elapsed around the course.

Braking While Cornering Test

The objective of this test is to measure vehicle stability in a transient state. Initial speed or braking is determined from the results of the cornering test. Initial speed and braking distance are recorded in order to compute an average acceleration. Stability is also noted during the test sequence below:

a. Mark a circle with a 46 m radius and 3.7 m wide;

b. Bring the vehicle to the speed determined in the cornering test;

c. Maintain this speed for at least half the circle;

d. Stop the vehicle as fast as possible without loosing control;

e. Record initial speed and braking distance.

2.2.3 Test Results

Braking Test

The summary test results are shown in Table 2.2

TABLE 2.2 BRAKING TEST RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	N/A	.155*	N/A	.151
compacted snow	.112	.090	.113	.080
dry ice	.069	.069	.059	.069
wet ice	.091	.075	.090	.065

* average deceleration (G)

Statistical analysis of the data identified no significant differences between vehicles, at a 95% level of confidence. Thus, the braking performance for both vehicles on a given surface and for a given loading condition was judged to be equal.

In addition, stability under braking was visually checked by the vehicle's maintenance of position inside a 3.7m wide lane and no differences were observed.

Static and Dynamic Pulling Ability Tests

Due to a failure of instrumentaion at the start of testing, no data was acquired for the dynamic pulling tests. The test results for the static pull tests are presented in Table 2.3.

TABLE 2.3 STATIC PULLING TEST RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	0.087*	N/A	0.155	N/A
compacted snow	0.221	0.217	0.188	0.171
dry ice	0.147	0.141	0.099	0.094
wet ice	0.112	0.053	0.084	0.023

* average coefficient of friction

Data analysis identified a significant difference between the two buses. The NEOPLAN articulated bus had a statistically significant lower static pulling capability than the MC-9. Also, due to its physical configuration, the Neoplan tractive ability on a grade was further reduced. This results from the higher number of axles which have to push snow in front of the tires, especially if the rear axle is not aligned perfectly, and thus, the rolling resistance is be higher.

Based on these results, it was recommended that the articulated bus should not be put in service during the winter wherever steep grades have to be climbed. This recommendation was confirmed during the test program when the NEOPLAN had to be towed after becoming stuck in a light snow after braking to a stop.

Cornering Test

The test results are presented in Table 2.4 and indicate that a significant difference between the two buses was found for the cornering test. This difference is about 10% and indicates that in any given turn, the MC-9 can be driven about 3.5% faster than the NEOPLAN. More importantly, the two vehicles exhibited very different road holding characteristics.

When the critical speed is reached, the MC-9 understeered. This resulted in loss of front-end adhesion and thus, the vehicle moved in a straight line to the outside of the curve or until the speed had lowered sufficiently to enable the driver to regain control. Thus, if the bus is driven at excessive speed, the vehicle will cut completely across one or more lanes of traffic before the driver can regain control. Also, when that critical speed is reached, body roll is large which could cause discomfort to the passengers.

TABLE 2.4 CORNERING TEST RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	N/A	N/A	N/A	N/A
compacted snow	.089*	.096	.083	.077
dry ice	.038	.030	.036	.025
wet ice	.064	.032	.051	.028

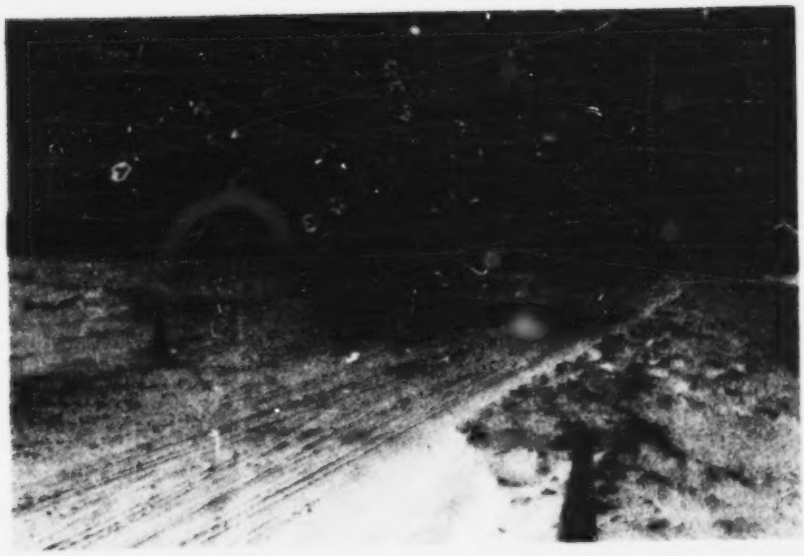
*** average lateral acceleration (G)**

The NEOPLAN exhibited markedly different steering characteristics. Whenever it reached critical speed, the front part of the vehicle remained very stable, however, the back-end started swinging to the outside of the turn due to oversteering of the rearmost axle. This resulted in the front part of the bus remaining within its lane while the back section swung out blocking another traffic lane. However, since the front end was still stable, lowering the speed slightly regained full control. In addition, at the critical speed, the body roll was very small compared to the MC-9. This reduced roll improved the passenger comfort and ride quality.

In conclusion, even though the MC-9 had a slightly higher critical speed than the NEOPLAN, it was noticeably less stable and would be less comfortable for passengers.

Lane Change Test

The analysis of the test results (Table 2.5) did not identify any significant differences between the two test vehicles. Stability observations noted previously in the cornering test also apply to the lane change test (See Figure 2.1).



NEOPLAN DURING LANE CHANGE

MC-9 DURING LANE CHANGE

FIGURE 2.1 LANE CHANGE PERFORMANCE

TABLE 2.5 LANE CHANGE TEST RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	N/A	N/A	N/A	N/A
compacted snow	61.2*	70.2	68.0	66.6
dry ice	33.2	37.2	31.9	35.0
wet ice	52.6	64.5	48.0	65.2

*Maximum speed (Kph)

Test Drive Course

Data presented in Table 2.6 indicates a significant difference between test buses over the course. The MC-9 was about 10% faster, however, since the course was starting from a standstill, much of the difference is accounted for by the superior starting tractive capability of the MC-9. Observations with regard to the stability noted for the cornering test also apply to this test.

TABLE 2.6 TRIAL TEST DRIVE RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	N/A	N/A	N/A	N/A
compacted snow	29.8*	30.1	28.6	27.5
dry ice	23.7	21.2	20.6	19.8
wet ice	27.5	20.8	25.7	17.5

* average speed (km/hr)

Braking While Cornering Test

The summary data for this test is presented in Table 2.7. The data analysis did not identify any significant differences between the buses. Observations with regard to the stability noted for the cornering test also apply to this test.

TABLE 2.7 BRAKING WHILE CORNERING TEST RESULTS

Surface	MC-9		NEOPLAN	
	Empty	Loaded	Empty	Loaded
fresh snow	N/A	N/A	N/A	N/A
compacted snow	0.126	0.117	0.119	0.106
dry ice	0.075	0.050	0.068	0.044
wet ice	0.092	0.075	0.079	0.071

* average acceleration (G)

2.2.4 Summary

Winter testing of both vehicles identified the following:

- no difference in braking performance and stability between the test vehicles;
- a difference in traction was measured under the static traction test with the MC-9 having 20% to 130% greater tractibility than the NEOPLAN;
- a slight difference in performance in the cornering performance was noted with the MC-9 capable of maintaining a critical speed about 3.5% higher than the NEOPLAN in a given turn;
- road-holding characteristics showed the NEOPLAN a more stable and more comfortable (less sway) bus than the MC-9;
- no difference in lane change performance was measured however the NEOPLAN was more stable and comfortable than the MC-9, due to less sway;
- the trial test showed the MC-9 about 10% faster on the prescribed course due primarily to better startability of the MC-9;
- no difference in braking performance while cornering was noted.

Overall, the performance of both buses are very nearly equal with the exception of traction and gradeability where the MC-9 offers much better performance. The NEOPLAN had generally better ride quality due to reduced sway.

2.3 HUMAN ENGINEERING COMPARATIVE EVALUATION

The purpose of this task was to compare basic human engineering design data on the prototype articulated bus and a conventional bus in service with Voyageur. Comparisons of these data with established human engineering standards permitted some relative assessment of these vehicles in terms of passenger accommodation and identified areas where significant design improvements could be made to the buses.

The work undertaken included:

- comparisons of the dimensional and geometric characteristics of the bus seats against human engineering standards;
- comparisons of seat pitch, recline angles and cushion quality;
- comparisons of the ease of operation of seat adjustments and associated seat equipment;
- comparisons of the vibration characteristics and ride quality of the seats in a variety of locations within the respective buses;
- comparisons of representative interior noise levels at a variety of speeds over typical highway surfaces;
- comparisons of the external engine noise;

2.3.1 Seat Design Comparison

The physical dimensions of the NEOPLAN and MC-9 passenger seats are summarized in Table 2.8. Comparisons of these dimensions with corresponding human engineering design guidelines (shown in the right-hand column) reveal that both the NEOPLAN and MC-9 seats have a number of design deficiencies. Whereas the NEOPLAN seat is more closely aligned with recommended values with respect to backrest width, seat squab angle, backrest angle and armrest height, the MC-9 seat appears to have a better backrest and headrest height, recline angle, seat pitch and lumbar support.

While the backrest of the NEOPLAN seat (in the upright position) is inclined at an ideal 115°, the backrest height of 67 cm, and consequently the headrest height, is far too short, resulting in inadequate head support. This problem would be particularly noticeable in the fully reclined position for which good head support is essential.

TABLE 2.8: SEATING DIMENSIONAL COMPARISONS

SEAT DIMENSION	NEOPLAN	MC-9	RECOMMENDED VALUE
Seat Height	44.5 cm	44.5 cm	38.1 cm - 43.2 cm
Seat Width	44.5 cm	44.5 cm	50.8 cm
Seat Length	45.7 cm	45.7 cm	43.2 cm
Backrest Height	67.3 cm	72.4 cm	86.4 cm
Backrest Width	43.2 cm*	42.5 cm	30.8 cm
Seat Squab Angle	11°* 11°	18° 18°	5-10° Upright 10-15° Reclined
Backrest Angle	115°*	107°	100°-125°
Recline Angle	14°	15°*	20°
Headrest Height	61.0 cm	63.5 cm	
Armrest Height	20.3 cm	19.7 cm	17.8 cm - 22.8 cm
Armrest Length	29.2 cm*	27.9 cm	35.6 cm
Pitch - min. max.	78.7 cm - 96.5 96.5 cm	90.0 cm - 91.4 cm	
Aisle Width	26.0 cm 38.7 cm	36.8 cm	
Sacral Gap	None	None	0 cm - 7.6 cm above SRP
Lumbar Support	10.2 cm Max Prot fusion above SRP	12.7 cm Max. Prot fusion above SRP	10.2 cm - 22.9 cm Height from SRP
Compression	0 cm (@ 68 kg)	3.81 cm (@ 68 kg)	

* Denotes the better seat

Another major problem with the NEOPLAN seat was that the lumbar support was located too low for the majority of the passenger population. An improperly designed lumbar support is perhaps the most important factor contributing to sitting discomfort. While the precise curve of the lumbar region of the back varies somewhat across the population, researchers recommend that the lumbar support be located in the region of 10 cm to 23 cm above the Sear Reference Point (SRP), defined as the midpoint of the junction of the planes of the compressed backrest and seat squab. Additionally, the point of maximum protrusion of the lumbar support should be located about 15 cm above the SRP. In the NEOPLAN seat, this point is located about 10 cm above the SRP. For the MC-9 it was 12.7 cm.

A third problem concerns seat pitch, defined as the spacing between consecutive seat rows. Seat pitch was found to vary within the NEOPLAN bus from a minimum of 79 cm to a maximum of 96.5 cm. Human engineering standards typically do not specify the minimum acceptable pitch because the amount of available leg room depends on the profile of the seat as well as on the spacing between seats. However, as a general rule, 89 cm is considered to be the minimum pitch for most low-profile passenger seats. For long trips, the minimum pitch should be increased to 96.5 cm or 101.6 cm. The majority of seats in the NEOPLAN bus had less than 89 cm pitch, thus creating potential kneee interference problems for adult passengers and severe ingress-egress problems for window passengers.

One of the advantages of the NEOPLAN seat is the quality of its cushion. As Table 2.8 shows, the cushion consisted of a relatively dense material which did not compress appreciably under a load of 68 kg over a 48 cm-diameter disc. In general, high-density cushions are considered very comfortable for prolonged sitting, as these types of cushions delay the onset of discomfort. The MC-9 seat cushions were considerably softer; however, they were considered acceptable.

It should be noted that although Table 2.9 shows the NEOPLAN and MC-9 seats to have the same width, the NEOPLAN seat was judged better since the aisle seats can be separated from the window seats by as much as 6 cm by depressing the release bar and sliding the seat into the aisle. Adjusting the seats in this manner, however, reduces the effective aisle width.

In summary neither the NEOPLAN seat nor the MC-9 seat completely conform to well-established human engineering guidelines. The major problems with the NEOPLAN seat include:

- a very short backrest,
- inadequate seat pitch, and
- a poorly-designed lumbar support.

2.3.2 Seat Controls and Adjustments

There are two types of recline controls for the NEOPLAN seat; pull-back levers for the window seat and press bars for the aisle seats (located on the seat frame beside the seat squab). Unlike the levers which were relatively easy to use, the press bars were difficult to reach while attempting to recline the seat. Moreover, the degree of effort required to recline the seat (e.g., overcome the return spring) was high. On the other hand, the effort required to recline the MC-9 seat was siginificantly less.

Although both the NEOPLAN and MC-9 footrests were similar in shape and method of operation, the NEOPLAN footrest was considered superior. Whereas the MC-9 footrest could only be set at one position, the NEOPLAN footrest was fully adjustable in height.

2.3.3 Internal Noise Levels

Overall A-weighted (dBA) and C-weighted (dBC) sound pressure levels for four vehicle speeds are provided in Tables 2.9 and 2.10 for each of the nine locations in the NEOPLAN and the six in the MC-9. The positions of these measurement locations are shown in Figure 2.2. The International Standards Organization (ISO) Rating Numbers are also shown in Table 2.9 and 2.10.

Comparison of the dBA noise levels presented in Tables 2.9 and 2.10 indicate that the MC-9 bus was considerably quieter than the NEOPLAN bus. Noise levels in the NEOPLAN bus ranged from 62 dBA to 85 dBA while in the MC-9, noise levels ranged from 68 dBA to 77dBA.

On the average, the noise levels in the NEOPLAN were nearly 6 dB higher (or twice the sound pressure level) than in the MC-9. Comparisons of the noise levels at corresponding seat locations and at the same vehicle speeds show that NEOPLAN noise levels were always higher than the MC-9.

Analysis of the data presented in Table 2.9 indicate that overall noise levels (in terms of dBA and ISO Rating Numbers) in the NEOPLAN were highest in the middle and rear of the front section (e.g., positions 3, 4, 5 and 6). The elevated noise levels in this area are due to the proximity of the engine, located below positions 3 and 4. Table 2.9 also demonstrates that overall noise levels in the NEOPLAN continually increase with the speed of the vehicle. The highest noise levels were found in seats 3, 4, and 5 at 100 km/h.

The noise levels produced by tne NEOPLAN were significantly higher than those produced by the MC-9. ISO Rating Numbers of 85 and 90 were obtained near the engine for the Neoplan compared to 80 for the MC-9. Based on the sound levels measured at the higher speed noise is expected to interfere with normal face-to-face communication in the Neoplan bus.

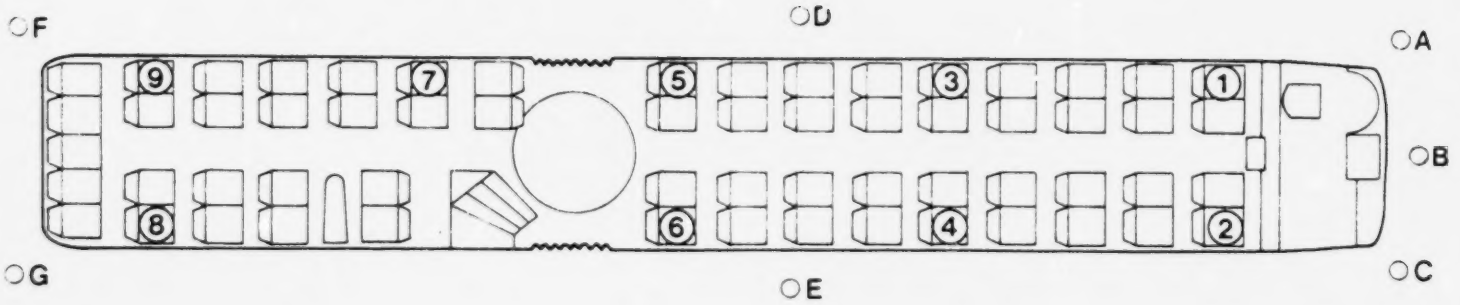
TABLE 2.9: INTERIOR SOUND LEVELS - ARTICULATED BUS

Position No.	Speed (km/hr)	ISO Rating Number	C-Weighting (dBA)	A-Weighting (dBA)
1	48	75	93	74
	64	75	96	74
	88	75	92	76
	100	80	96	79
2	48	70	92	72
	64	80	95	74
	88	80	94	77
	100	80	95	78
3	48	80	96	76
	64	85	95	75
	88	85	96	79
	100	80	97	83
4	48	75	93	75
	64	90	96	76
	88	85	96	79
	100	90	99	85
5	48	75	95	73
	64	75	95	77
	88	80	94	78
	100	80	96	81
6	48	80	94	74
	64	80	94	74
	88	75	94	78
	100	90	100	84
7	48	70	92	72
	64	75	92	72
	88	85	93	78
	100	85	98	83
8	48	65	92	63
	64	70	94	66
	88	80	100	76
	100	85	96	77
9	48	65	90	62
	64	65	94	64
	88	80	92	73
	100	80	96	75

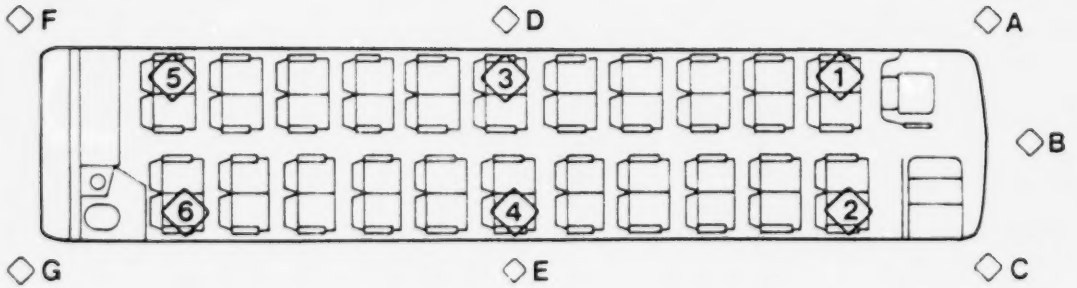
TABLE 2.10: INTERIOR SOUND LEVELS - MC-9 BUS

Position No.	Speed (km/hr)	ISO Rating Number	C-Weighting (dBA)	A-Weighting (dBA)
1	48	65	90	68
	64	65	01	70
	88	70	90	69
	100	70	93	73
2	48	65	91	69
	64	70	92	69
	88	70	91	71
	100	70	95	73
3	48	70	92	71
	64	70	95	69
	88	70	97	70
	100	75	94	72
4	48	70	91	69
	64	75	96	70
	88	70	98	69
	100	75	98	72
5	48	70	90	73
	64	80	92	73
	88	75	91	73
	100	90	96	77
6	48	70	89	70
	64	75	92	73
	88	80	92	75
	100	90	96	75

FIGURE 2.2 SOUND MEASUREMENT POSITIONS



NEOPLAN



MC-9

2.3.4 External Noise Levels

Overall A-weighted (dBA), C-weighted (dBC) sound pressure levels and ISO Rating Numbers for seven locations are shown for the Neoplan bus in Table 2.11. In the Neoplan, the msximum noise levels of 88 dBA and 87 dBA were obtained near the middle of the bus at locations D and E. In the MC-9, the maximum noise levels of 82 dBA were obtained at the back at locations F and G. The locations of maximum noise levels correspond to the location of the engines of the two buses.

The maximum ISO Rating Number for the MC-9 was 80. Maintenance personnel exposed to noise at this level do not require protective devices. The noise levels produced by the Neoplan were significantly higher than those produced by the MC-9. ISO Rating Numbers of 85 and 90 were obtained near the engine. At these levels, maintenance personnel exposed to noise at these levels for long periods of time on a regular basis should use hearing protection devices.

TABLE 2.11: BUS EXTERNAL SOUND LEVELS AT IDLE

Location	ISO Rating Number		C-Weighting (dBA)		A-Weighting (dBA)	
	Neoplan	MC-9	Neoplan	MC-9	Neoplan	MC-9
A	80	65	90	83	79	63
B	75	60	90	82	76	62
C	75	60	90	80	74	62
D	90*	70	100	92	88	72
E	85	70	95	84	87	70
F	65	80**	86	91	68	82
G	65	80	79	88	64	82

* Neoplan Exhaust
** MC-9 Exhaust

2.3.5 Vibration and Ride Quality Assessment

The results of the vibration measurements are presented in Tables 2.12 and 2.13 for the NEOPLAN bus and the MC-9 bus respectively. Recommended reduced comfort exposure limits (LIMIT), derived from ISO 2631 (Guide for the Evaluation of Human Exposure to Whole-Body Vibration) are provided in the tables beside each of the measured values. These limits specify maximum daily exposure limits (in terms of 1 min, 16 min, 25 min, 1 hr, 2.5 hr, 4 hr, 8 hr, 16 hr and 24 hr) as a function of the intensity, frequency and direction of the vibration. Exposure beyond the limits provided in the tables may lead to discomfort and interfere with activities such as eating, reading and writing.

TABLE 2.12: VIBRATION LEVELS AND RECOMMENDED REDUCED COMFORT EXPOSURE LIMITS FOR THE NEOPLAN ARTICULATED BUS

POSITION	48 km/h A(rms)	48 km/h LIMIT	64 km/h A(rms)	64 km/h LIMIT	88 km/h A(rms)	88 km/h LIMIT	100 km/h A(rms)	100 km/h LIM	Mean A(rms)
Driver	.22	4	.21	4	.33	2.5	.45	1	.30
1	.50	1	.32	2.5	.43	1	.51	1	.44
2	.52	1	.34	2.5	.43	1	.42	1	.43
3	.50	1	.25	2.5	.50	1	.44	1	.42
4	.36	2.5	.21	4	.47	1	.40	1	.36
5	.35	2.5	.24	2.5	.58	.4	.48	1	.41
6	.31	2.5	.29	2.5	.55	1	.59	.4	.44
7	.42	1	.28	2.5	.31	2.5	.38	2.5	.35
8	.25	2.5	.35	2.5	.51	1	.49	1	.40
9	.33	2.5	.44	1	.44	1	.60	.4	.45
Average	.38		.29		.46		.48		.40

TABLE 2.13: VIBRATION LEVELS AND RECOMMENDED REDUCED COMFORT EXPOSURE LIMITS FOR THE MC-9 BUS

POSITION	48 km/h A(rms)	48 km/h LIMIT	64 km/h A(rms)	64 km/h LIMIT	88 km/h A(rms)	88 km/h LIMIT	100 km/h A(rms)	100 km/h LIM	Mean A(rms)
Driver	.21	4	.32	2.5	.34	2.5	.41	1	.32
1	.35	2.5	.45	1	.39	1	.46	1	.41
2	.32	2.5	.37	2.5	.52	1	.42	1	.41
3	.27	2.5	.28	2.5	.27	2.5	.41	1	.31
4	.43	1	.36	2.5	.33	2.5	.39	1	.38
5	.35	2.5	.43	1	.46	1	.61	.4	.46
6	.32	2.5	.45	1	.47	1	.60	.4	.46
Average	.32		.38		.40		.47		.39

NOTE:

1. A(rms) is the root mean square acceleration in the longitudinal direction measured in m/sec/sec.

2. LIMIT is the recommended reduced comfort exposure limit per 24 hour period derived from the ISO 2631. The exposure limits are given in hours.

The vibration levels obtained in the NEOPLAN bus and the MC-9 bus impose no practical restriction on the operation of either bus from the health and safety standpoint. The maximum safe exposure limit, derived from ISO 2631, for the highest levels of vibration in either bus was 16 hours.

Tables 2.12 and 2.13 present the mean A(rms) values for each seat across all speeds (given at the end of each row) and also the mean A(rms) values for each speed across all seats (given at the bottom of each column). These mean values are useful for making relative assessments of ride quality. For example, comparing the mean A(rms) for the driver's seat with mean values for the other seats in the NEOPLAN, it is evident that the driver's seat (with a mean A(rms) of .30) is considerably smoother. Similarly, the driver's seat in the MC-9 gives a smoother ride than the other seats. Furthermore, the ride quality of the driver's seats in the two buses is equivalent.

A great deal of the variability observed in A(rms) was attributed to variability in road condition. This was confirmed by making repeated observations in the same seat at the same speed. During that trial, the A(rms) ranged from .44 to .60. In summary, there was no practical difference in the ride quality of NEOPLAN seats and the MC-9 seats as there was as much variability between seats in the same bus as there was between seats in the two buses.

2.4 DRIVER TRAINING

In general, Voyageur's approach to both driver and mechanic training on the articulated bus was to achieve orientation and familiarization through hands-on practice in driving the bus. The assumption underlying the training program was that if the employee who is proficient on regular buses learns the difference between the regular bus and the articulated bus, then the employee will be capable of driving and/or servicing the articulated bus.

The training program was divided into two phases as shown in Figure 2.3. The first phase consisted of a 6 day training course to drivers responsible for the Ottawa-Montreal articulated bus route. The second phase involved training extra drivers while they are on 'spare' (e.g., driver is on call but not assigned).

2.4.1 Instructor Training and Experience

Testing and Training Staff

The Voyageur employees with the most experience on the bus were the employees in the maintenance department who were responsible for the initial tests of the articulated bus. These employees drove the bus for hundreds of hours during the testing program in different conditions and climates, and were thoroughly familiar with its operation.

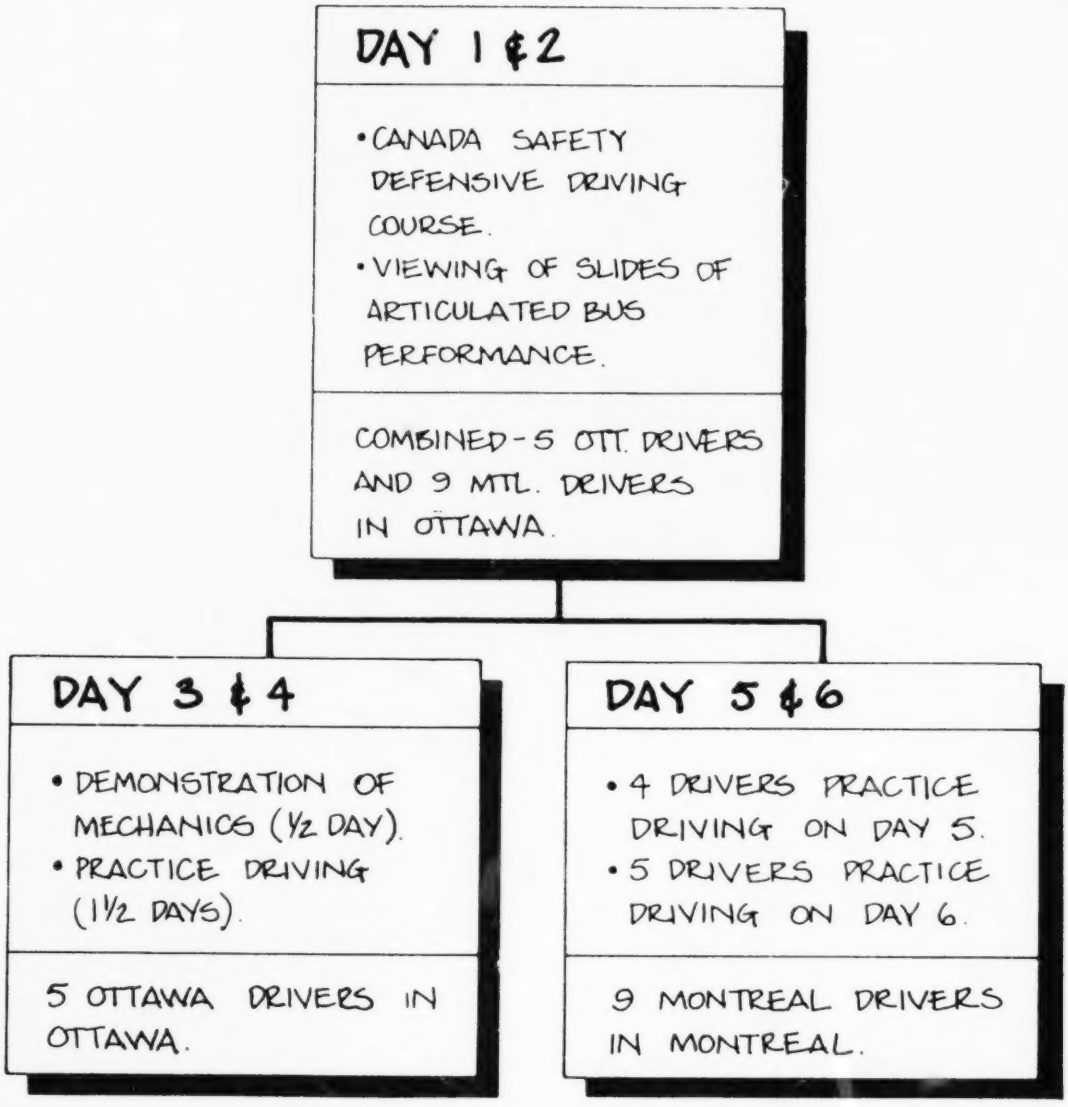

DAY 1 & 2
• CANADA SAFETY DEFENSIVE DRIVING COURSE.
• VIEWING OF SLIDES OF ARTICULATED BUS PERFORMANCE.
COMBINED - 5 OTT. DRIVERS AND 9 MTL. DRIVERS IN OTTAWA.
DAY 3 & 4
• DEMONSTRATION OF MECHANICS (½ DAY).
• PRACTICE DRIVING (1½ DAYS).
5 OTTAWA DRIVERS IN OTTAWA.
DAY 5 & 6
• 4 DRIVERS PRACTICE DRIVING ON DAY 5.
• 5 DRIVERS PRACTICE DRIVING ON DAY 6.
9 MONTREAL DRIVERS IN MONTREAL.

FIGURE 2.3: PHASE I TRAINING PROGRAM.

The Voyageur officer responsible for training drove the bus, under the direction of the testing crew for approximatley 10 hours, in various traffic and road conditions. Through this exercise, he learned the features and capabilities of the bus which were most important to include in the training program.

The training officer then taught a driver instructor through a program which included 10-15 hours of experience driving the bus in various conditions ranging from country roads to congested urban traffic environments.

2.4.2 Training Materials

As described previously, the training approach was through hands-on practical experience. Consequently, training materials do not constitute a significant component of the program. The materials used included:

- a list of "comparison features" which identified the way in which the handling and capabilities of the articulated bus compared with a regular bus;
- a set of 40-45 slides depicting the bus turning, backing and at various angles aimed at illustrating the way the bus moved and functioned including the amount of space required for various maneuvres.

2.4.3 Driver Selection

Drivers selected for Phase 1 of the training were identified entirely on the basis of the proposed schedule for the articulated bus. Both drivers and spares responsible for the departures on which the articulated bus was scheduled and those departures immediately after the scheduled mid-day departures were selected for training.

Of the 14 drivers who received training, 9 were from Montreal and 5 were from Ottawa. Because the Ottawa - Montreal route is a seniority route, all drivers who received training had a minimum of 13 years of driving experience. Drivers who received training were the primary driver or as a spare for the following routes:

8:00 AM - Montreal - Ottawa
12 NOON - Ottawa - Montreal
* 1:00 PM - Ottawa - Montreal
4:00 PM - Montreal - Ottawa
* 5:00 PM - Montreal - Ottawa
9:00 PM - Ottawa - Montreal
* 10:00 PM - Ottawa - Montreal

Drivers on those departures not scheduled for the articulated bus were also trained in case a bus was delayed causing the schedule to slip and thus requiring the articulated bus to be driven on a later departure.

---

* Routes which are not scheduled for the articulated bus.

2.4.4 Phase 1 Training Activities

Phase I training consisted of a six day course. On days 1 and 2, all 13 trainees were trained together, while on the remaining days Montreal and Ottawa drivers received separate two day sessions.

Figure 2.3 provides an overview of the 6 day course. The Canada Safety Driving Course was given to all 14 trainees in Ottawa for the first two days. During this course, the drivers also had an opportunity to view the slide package and review the list of comparison features for the NEOPLAN.

On days 3 and 4 of the course, the Montreal drivers returned to regular scheduled duties in Montreal while the 5 Ottawa drivers received one-half day training on the NEOPLAN at the Ottawa garage. Mechanics who had worked on the bus in Montreal were brought to Ottawa to instruct the drivers on some of the basic mechanical and structural differences between the NEOPLAN and regular Voyageur equipment.

Half of the third day and the entire fourth day were devoted to "on the road" practice. All 5 drivers stayed in the bus, taking turns driving the bus in various conditions under the direction of the driving instructor. Each driver drove in highway, urban and rural traffic conditions.

The 9 Montreal drivers were divided into two groups of 4 and 5 to obtain their practice driving experience. Four drivers spent day 5 on the bus and the remianing 5 drivers spent day 6 on the bus, obtaining the hands-on experience which the Ottawa drivers had received on days 3 and 4.

Before certifying a driver, both the instructor and the driver had to be confident that the driver was comfortable and familiar with the bus and knew how to handle the most difficult situations. Each driver had a minimum of three hours experience with the bus.

2.4.5 Phase 2 Training Activities

Once the drivers who were scheduled to drive the articulated bus had been certified, Voyageur initiated Phase 2 of the program. The objective of the second phase is to ensure that all Voyageur drivers in Ottawa and Montreal are capable of driving the bus, and all Voyageur mechanics are capable of servicing the NEOPLAN.

Mechanical Training: The bus had been in the Montreal garage for one year prior to its operation, at which time a number of modifications were made to meet Canadian standards. In the course of the work, all Montreal mechanics had an opportunity to work on the bus and learn how it differed from regular buses. The foreman in Montreal assumed responsiblity for these modifications and developed a comprehensive knowledge of the bus.

A few Montreal mechanics came to Ottawa and instructed the foreman and 2 mechanics in Ottawa on the differences between the articulated and the regular bus. To do this the two buses were parked side by side in the garage and examined in detail.

Driver Training: When drivers are on-hand as spares at the station and are not driving they are paid a non-productive minimum salary. Phase 2 of the training program utilizes this time to schedule spare drivers to practice driving the articulated bus when it is not in operation. This program involved 2 or 3 drivers on the road with a driving instructor, practicing in the bus in all driving conditions. Spares were selected for training according to seniority.

2.5 TERMINAL MODIFICATIONS

During the pre-demonstration phase of the project, Voyageur undertook a review of their terminal configurations to ensure that the larger bus could be accommodated. This review consisted of assessing both the length and height problems involved in operating the bus into the Ottawa, Montreal and Quebec terminals. In addition, the maintenance facilities in each centre were assessed.

2.5.1 Terminals

All the terminals were assessed as to capability of accommodating the larger dimensions of the articulated bus and the vertical bending restriction imposed by the articulation joint. All the terminals were surveyed according to their site plans and assessed against these criteria to develop a list of physical changes required before a demonstration could commence.

Montreal Terminal

The station layout for the Montreal terminal which is at the corner of Berri Street and de Maisoneuve Blvd. is presented in Figure 2.4. The analysis indicated that there was no access or manoeuvreability problem for the buses in to or out of the terminal. However, because of the excessive length, there was a restricted traffic flow in the loading bay. In order to maximize the manoeuvring space behind the bus, the northern-most loading bays were identified for use by the articulated coach. There was no height problem for the coach at this terminal. For longer-term bus parking there was no significant problem identified.

Quebec Central Station

Entrance and egress of the bus from the station does not present a problem . The loading bay configurations did present some problems for the articulated bus as any of the proposed parking spaces resulted in the rear of the bus extending into St. Helen's Street by about 1 metres.

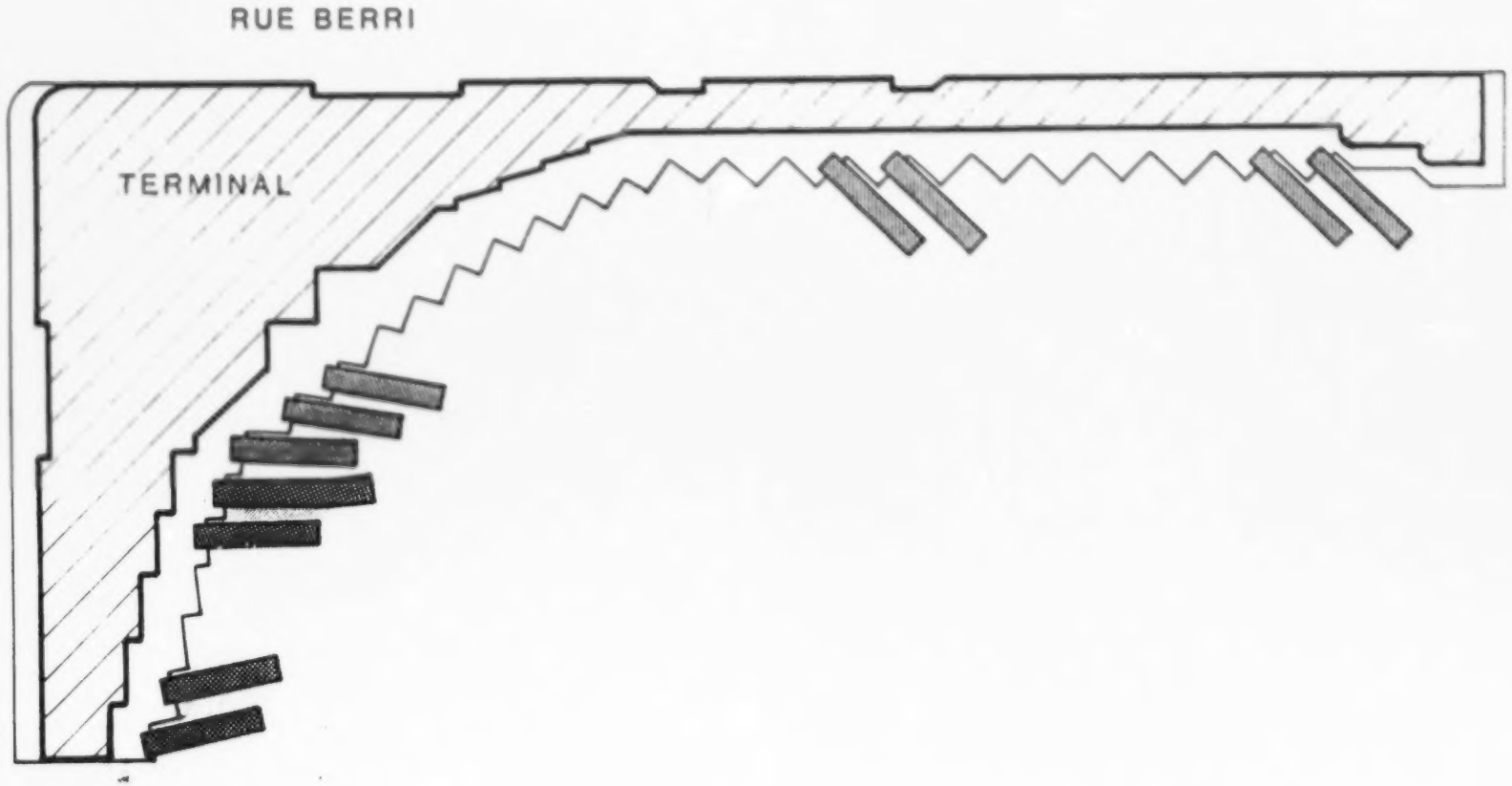


FIGURE 2.4: MONTREAL TERMINAL LAYOUT

A potential solution for this problem was to load the bus from the rear of the station which requires passengers to cross St. Helen's Street or to use the parking lot for embarking and debarkation which also would result in passengers having to cross St. Helen's Street.

Ottawa Terminal

There was no access problems identified at the Ottawa terminal (Figure 2.5) with all curb angles sufficient for negotiation by the bus. The loading bays were of sufficient height in the terminal. For operational reasons, the bays at the western end of the terminal were reserved for the articulated bus. The quick maintenance area at the terminal was sufficiently large to handle the articulated bus. No other traffic or parking problems were anticipated at this station.

Dorval Terminal

The Dorval terminal (Figure 2.6) presented no problems for the operation of the bus as it had been designed to accommodate a larger bus. Therefore, there was one bay which could handle a longer bus with excessive height.

Montreal Maintenance Facilities (Bonaventure Garage)

The original entrance way into the garage was too small to accommodate the extra height of the articulated coach and therefore the St. Thomas Street entrance was enlarged to 6 x 9 metres. In addition, as this was to be the principal maintenance facility for the coach, a special hydraulic lift was installed which was capable of lifting an articulated bus. This installation is shown in Figure 2.7. No other significant modifications to this facility were required.

Ottawa Maintenance Facility

The entrance to the Ottawa garage was of sufficient height; but the ramp required modification to reduce the vertical jacknife angle. This facility was intended to be an emergency maintenance site for the coach and thus no installation of lift equipment was required. If necessary an electric hoist could be employed for maintenance operation. Because of the size of the maintenance facility in Ottawa, no internal vehicle circulation problems were foreseen.

Quebec Maintenance Garage

The Quebec garage was also intended only as an emergency maintenance site. No modifications to the entrance and exit doors were required and the automatic bus washing equipment was tall enough to accommodate the bus.

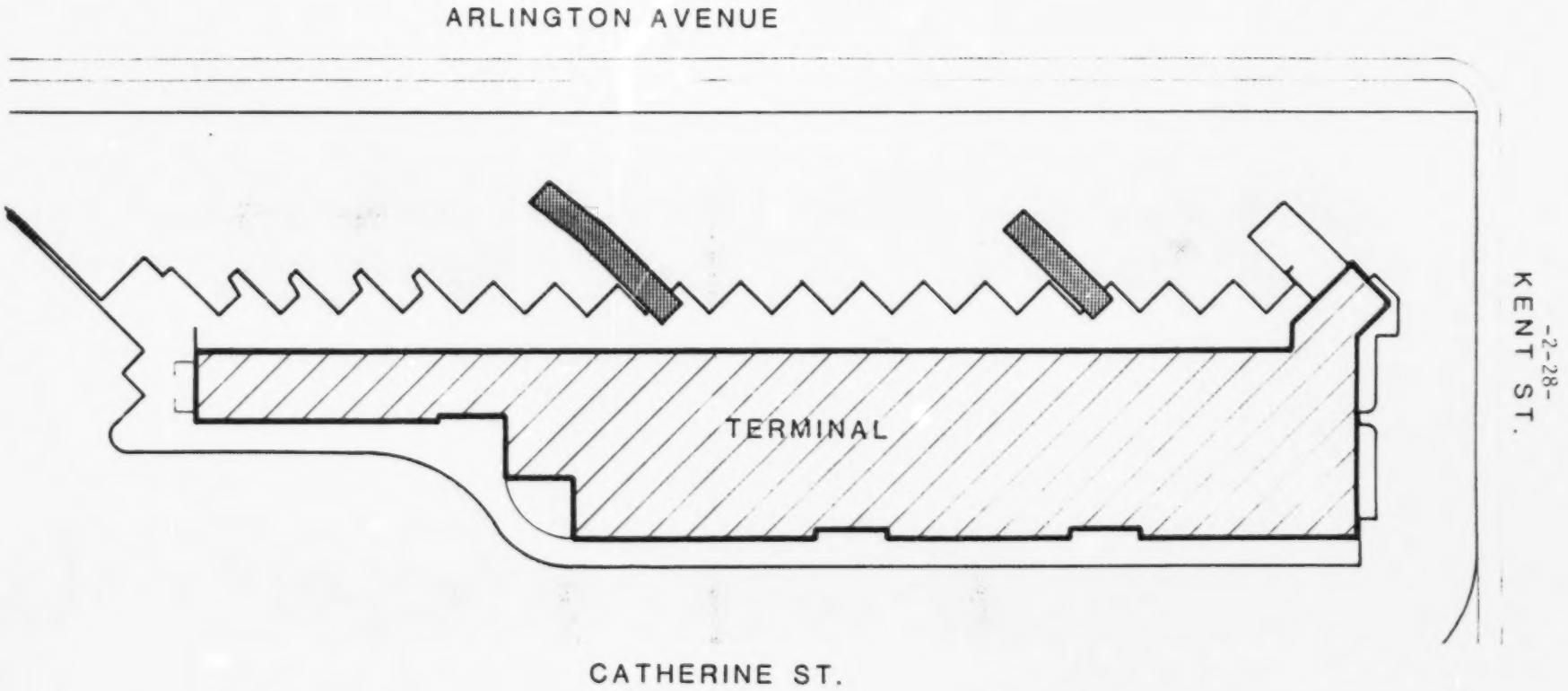


FIGURE 2.5: OTTAWA TERMINAL LAYOUT

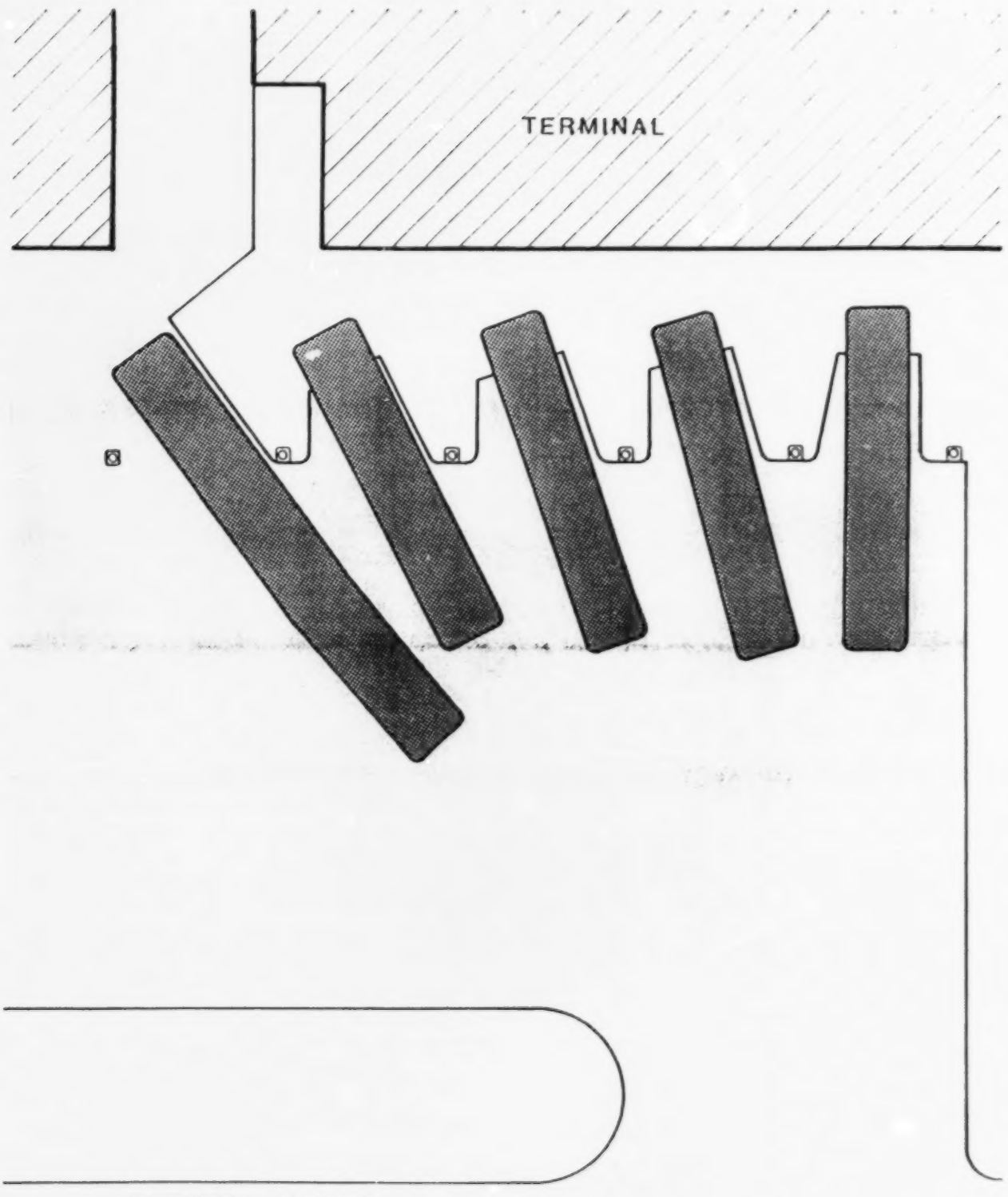


FIGURE 2.6: DORVAL TERMINAL LAYOUT

FIGURE 2.7: HYDRAULIC LIFT FOR ARTICULATED BUS

2.6 PRE-DEMONSTRATION VEHICLE MODIFICATIONS

Prior to introduction of the NEOPLAN into the service demonstration, Voyageur experienced numerous maintenance and design problems with the vehicle. Unfortunately many of the repairs made to the NEOPLAN were not properly reported on work orders and thus, some maintenance history was missed. This section reviews several of the problems that were encountered with the NEOPLAN during the pre-demonstration period.

Windshield: The vehicle suffered from chronic windshield water leakage through to the interior of the bus, requiring repeated repairs by NEOPLAN and by Voyageur. This problem however is not specific to the NEOPLAN but is relatively common with all of Voyageur's buses.

Electrical Wiring: The NEOPLAN suffered from severe electrical wiring harness problems. As the bus was equipped with a North American power plant, it had a larger capacity alternator compared to European power plants. In Europe, 125-amp 24 volt alternators are common while in North America, and specifically at Voyageur, 380-amp 24 volt alternators are used. NEOPLAN, at the time of power plant installation, omitted to replace the wiring harness with one of higher capacity. Consequently, the European wiring harness failed under the higher amperage loads generated by the North American alternator resulting in an onboard fire. The problem was resolved by Voyageur by installing larger capacity wiring harness.

Circuit Breakers: During the initial testing, the bus experienced a high frequency of failures of the European-style circuit breakers. These breakers had a tendency to overheat to the point of melting the breaker receptacle, making them difficult to replace. Additionally, the NEOPLAN had all wiring harnesses grouped together into a large bundle and, in the opinion of Voyageur, this could lead to the destruction of the whole wiring harness if one wire failed.

Air Conditioner Controls: Excessive maintenance problems were encountered with the air conditioner electronic control system. NEOPLAN used sixteen different air distribution motors throughout the bus instead of having the typical North American single drive system. Shortly after the unit's arrival in Canada, problems with the air conditioning controls were experienced. These were diagnosed as being caused by the special electronic temperature control circuit box. Three of the sixteen control units were replaced during the pre-service demonstration. Evaluation of the problem led NEOPLAN to modify the system to a direct relay mechanical system. This modification was performed prior to the service demonstration after which no additional air conditioning control problems were experienced.

Air Conditioner Cooling: Because the air conditioning power plant was installed near the main fuel tank, its exhaust caused the fuel to reach unacceptably high temperatures. Voyageur solved the problem by insulating the main fuel tank with insulation wool and sheet metal barriers to ensure that the tank would operate within its normal operation temperature range. Once modified, the main engine operated more efficiently with improved engine cooling. The modification to the air conditioning power plant installation did not however correct the local air temperature problem. As a result, the exhaust from the air conditioning power plant heated the air conditioning compressor enough to cause the diesel fuel pump to fail due to seal degradation.

Air Conditioner Condensate: The air conditioning distribution system exceptionally used in the NEOPLAN bus was exceptional poorly designed with catchment troughs for the condensate running the length of the bus. These troughs did not work as intended and water dripped from them whenever the bus swayed or encountered large bumps. Because these troughs were located directly over the passengers, the passengers frequently got wet. The corrective action taken was to attempt to improve the speed of water draining in the system through improved hosing. It is to be noted that in other NEOPLAN buses imported into North America (eg. Golden Nugget Inc. of New Jersey), similar problems were encountered which resulted in a complete redesign of the air conditioning system. No redesign was undertaken for this demonstration.

Insulation: The insulation in the walls of the NEOPLAN was solid styrofoam panels precut to size and inserted between the outside structure and inner facing of the bus. During a modification to the rear lavatory section, Voyageur observed that the styrofoam had shrunk creating significant air spaces all around the panels. This shrinkage problem explained the excessively cold wall surfaces inside the NEOPLAN during winter operation. Although no corrective measures were taken, it was suggested that if the bus operated for a longer period of time, Voyageur would have experienced significant condensation on the interior walls which would promote early corrosion of the side walls of the vehicle.

Exhaust System: The exhaust system that had been designed and developed for the Detroit diesel 8V-92TA engine was considered to be satisfactory for systems with few restrictions. However, it presented a problem with the NEOPLAN where the exhaust exited the side of the bus at passenger level. The excessive noise from the exhaust system was evident in the NEOPLAN. In addition, the fumes and smell from the exhaust system tended to leak into the bus at the articulated joint when the NEOPLAN idled. This resulted in a tendency for the inside of the centre section of the bus to fill with exhaust odours. Solving the exhaust system problem is considered to be very difficult because of the complexity of modifying the exhaust system such that it can traverse the articulated joint to exhaust at the rear of the bus. No modifications were undertaken.

Cooling System: Because the NEOPLAN was originally designed to accommodate a European diesel engine, the cooling capacity of the system was undersized for the North American engine used. As a result, there was a tendency for the bus to overheat when operating at maximum speeds. Modifications to the cooling system were made by enlarging the opening in front of the radiator and modifying the grill fins to allow for maximum air flow and thus increase the cooling capacity. These modifications did help to control the maximum temperature of the engine, but were viewed as temporary measures.

Hydraulic Motors: The hydraulic fan and motor used to cool the radiator was improperly insulated for vibration on its mountings and created significant vibration and noise inside the bus. After numerous attempts to improve the situation, Voyageur redesigned the mounting of the hydraulic motor thereby curing the problem.

Door Hinges: The engine compartment hinges failed and were rewelded on a number of occasions indicating under-design of the hinges for this very large and heavy door.

Engine Soundproofing: The main power plant was inadequately soundproofed and thus generated higher than normal noise levels inside the passenger compartment. Voyageur's difficulties in correcting the problem were compounded by the lack of space available between the engine compartment and floor of the NEOPLAN. Part of the problem was resolved by adding sheet metal to act as a heat and noise barrier for the turbo charger which rested very close to the floor. However the problem was not fully resolved due to the lack of space available for the addition of soundproofing over the engine.

Lavatory Modifications: The lavatory on the NEOPLAN bus was exceptionally small by North American standards. In particular, the head room was deemed to be too low and therefore modifications were undertaken to increase the height of the lavatory as well as the entrance door.

Destination Sign: The bus as ordered from Germany did not include a destination sign which is the norm for Voyageur equipment. This sign was subsequently installed by Voyageur's maintenance staff.

Window Push-Out Pressure: The windows on the bus were of a pop-out variety currently used in Europe. Originally, the bus had higher push-out pressures than required in North American. The spring tension in the releases was modified to lessen the push-out pressure to conform to North American regulations.

2.7 PASSENGER SURVEY

A passenger survey was undertaken to compare passenger reactions to the articulated bus and the standard bus. Particular areas of interest included passenger comfort, onset of discomfort in various body regions over a prolonged journey, causes of passenger discomfort and passenger evaluation of equipment. The test was conducted on the relatively long duration route of Toronto to Montreal (6 hour trip).

Participants for the survey were recruited by advertising in the media. Successful candidates were selected on the basis of sex, age, height and weight to represent the general Canadian population. A total of about 109 passengers participated in the survey.

Four equal groups of 30 participants were assigned to the schedule shown in Table 2.14.

TABLE 2.14: PASSENGER SURVEY

DATE	BUS	ROUTE	GROUP	SIZE
27/2/81	Neoplan	TOR-MTL	A	29
27/2/81	Neoplan	TOR-MTL	B	24
28/2/81	MC-9	TOR-MTL	C	25
1/3/81	MC-9	MTL-TOR	A	34
2/3/81	MC-9	TOR-MTL	D	31
3/3/81	MC-9	MTL-TOR	B	19
4/3/81	Neoplan	MTL-TOR	C	24
4/3/81	Neoplan	MTL-TOR	D	31

Each of the 109 passengers completed a series of questionnaires during the bus trip to Montreal and again during the return trip to Toronto. In this way, each passenger experienced the ride aboard both buses, thereby permitting more reliable statistical comparisons to be made between the Neoplan bus and the MC-9 bus.

The questionnaire consisted of eight separate sections - a PRE-TRIP Section, six HOURLY Sections and a POST-TRIP Section. Each section of the questionnaire was distributed at appropriate time intervals during the trip and collected immediately upon completion.

The first section, the PRE-TRIP Section, was administered just prior to departure. It contained several questions about the passenger's physical characteristics which provided some measure of the validity of the sample.

The HOURLY Section contained questions designed to provide subjective discomfort levels as a function of time. The first of a series of six HOURLY SECTIONS was administered together with the PRE-TRIP Section just prior to departure and the remaining 5 were handed out at one hour intervals during the six hour trip.

Just prior to arrival, passengers were given the POST-TRIP Section to complete. This section contained 35 forced-choice questions concerning the design characteristics of the seat, the bus environment and the adequacy of washroom facilities.

The analysis of the data indicated that:

- Based on the hourly comfort ratings, (eg., comparisons of hours 5 and 6), the Neoplan bus is less comfortable than the MC-9;
- Responses suggested that the MC-9 bus seat is less comfortable in the upright position;
- Respondents stated the headrest of the NEOPLAN seat is far too low;
- The two most significant design problems with the MC-9 seat were seat width and recline angle;
- The two most significant problems with the Neoplan seat were the headrest and cushion density (about half of the Neoplan passengers reported that the cushion was too firm);
- The NEOPLAN backrest did not provide adequate lumbar support;
- The washroom facility aboard the Neoplan bus was judged to be conveniently located but the ceiling too low;
- Respondents stated that noise levels in the NEOPLAN bus were excessive.

Many of these results supported the findings of the human engineering evalution. However, seat pitch was not considered as significant a problem in the NEOPLAN bus by the passengers as had been predicted. In fact, the headrest, seat cushion, storage space and seat width were reported to represent more significant problems. In contrast, seat pitch was the third most significant problem reported for the MC-9 seat, despite the fact that on average the actual seat pitch in this bus was greater than in the NEOPLAN bus. The reasons for this are not immediately apparent, through it is possible that other problems with the NEOPLAN seat are relatively more important than those of the MC-9, or NEOPLAN passengers may have avoided the seats with the least amount of pitch. A third possibility is that seat pitch and seat recline are highly interdependent in terms of their effect on overall comfort and that the improved recline of the Neoplan seat compensated to some extent for the inadequate pitch.

Based on the survey, it is difficult to state that one bus is clearly superior to the other from the human factors point of view. Certainly, both buses have design deficiencies, some of which may be significant from the operation and passenger acceptance standpoint.

3.0 REVENUE SERVICE DEMONSTRATION EXPERIENCE

3.1 DEMONSTRATION PLAN

The original program plan called for the testing of one articulated bus in revenue service for one year at which point a decision to procure an additional four vehicles would be made. In order to get the maximum exposure of the vehicle for both testing and marketing purposes the following criteria for the experimental service routes were defined:

- high density volume of the passengers,
- short-haul route,
- an express route,
- terminal facilities are appropriate,
- high frequency of departures.

These criteria defined two possible routes in the Voyageur system:

- Montreal/Ottawa,
- Montreal/Quebec City.

These two routes were compared and ranked with the Montreal/Ottawa route coming out as the preferred choice by the Voyageur management team. This decision was primarily based upon the better accomodation of the bus at the Montreal or Ottawa terminals. Further, both Ottawa and Montreal had large well equipped service facilities which could handle the articulated bus.

The initial route schedule was defined to maximize passenger volumes. The initial schedule is shown in Table 3.1.

TABLE 3.1: DAILY SCHEDULE FOR OPERATION OF THE NEOPLAN ARTICULATED BUS OTTAWA - MONTREAL ROUTE

ROUTE	DAILY	ALTERNATIVE
Depart Montreal	0800	
Arrive Ottawa	1010	
Depart Ottawa	1201	1300
Arrive Montreal	1410	1525 (D)
Depart Montreal	1600	1700
Arrive Ottawa	1810	1935 (D)
Depart Ottawa	2100	2200
Arrive Montreal	2325 (D)	0010

(D) - Operates via Dorval

Under normal circumstances the bus was to follow the schedule outlined under the "daily" column. In cases where qualified operators were not available for specific departures, then the alternate schedule listed in Table 3.1 would be used.

While the original intention of the project was to establish a group of control buses on the demonstration route, because of a concurrent reduction in fleet size which increased the utilization and mobility of the buses within the Voyageur system, no single control group of buses was able to be maintained. This lack of a set of control buses subsequently posed significant problems in comparing maintenance behaviour of the articulated bus versus regular 12.2 metre coaches. This problem was overcome in part by using the general maintenance management information system and selecting out five standard MC-9 buses of comparable vintage. All of these buses were in mainline service although they were not dedicated to the Montreal/Ottawa route.

The revenue introduction of the NEOPLAN was inaugurated on December 4, 1981. The bus maintained the planned operating schedule through to December 31, 1981 at which time a major failure occured in the articulated joint. This was apparently due to an acute turn undertaken at the maintenance garage. The failure was repaired but due to the potential safety hazard the bus was removed from service for further mechanical design analysis.

These tests were undertaken in the spring of 1982 and are described later in this chapter. In the summer of 1982, after an assessment of the modification requirements to convert the bus into a unit which would not have the number of recurring small problems e.g., dripping air conditioning system, a decision was made to cancel further testing of the bus. The bus was garaged until it was sold to another operator for city tour service in 1982.

3.2 MAINTENANCE EXPERIENCE DURING SERVICE

This section describes the Voyageur's maintenance experience with the NEOPLAN bus. The conclusions regarding the maintenance experience were drawn from information obtained through interviews with foremen, mechanics, and repairmen, as well as from collected maintenance data. The quantitative analysis of the maintenance experience of the articulated bus is restructed however, by the short duration of the demonstration and the single unit tested.

Similarly, evaluation of the service life of individual components was not possible because of the relatively brief operational history.

3.2.1 Major Problem Areas

Heating and Ventilation System: The heating/ventilation system of the NEOPLAN articulated bus proved to be highly unreliable. Passenger comfort suffered as a result of condensate dripping onto passengers, cold air drafts from vents and poor temperature control. These problems had been identified prior to the service demonstration as reported in Chapter 2.6.

Turntable Problems: Repairs to the turntable stops were needed as a result of the vehicle being backed up at too sharp an angle. Failure occurred in a main structural support thereby creating a hazardous situation for the operation of the articulated bus. Repair consisted of the addition of gussets to strengthen the structure. However, two days later the articulated joint failed again. This time structural failures were more extensive and the vehicle was removed from revenue service. A major analysis program was instituted (discussed in Section 3.3) which resulted in recommendation for the termination of the demonstration.

Engine/Transmission/Driveline: Another major problem area resulted from a mismatch of the engine/transmission/drivetrain. This mismatch was the result of a misinterpretation of the vehicle performance specification. The vehicle performance specification required that the maximum speed of the articulated bus would be limited to 100 km/h. As a result of this limitation, the engine/transmission/ drivetrain was matched to the maximum speed, such that the engine at 100 km/h rotated at maximum governed RPM. The extended operation of the engine at high RPMs, caused exhaust valve and engine failures on two occasions. Fortunately, these engine failures were covered under warranty at no cost to the project.

Voyageur proposed to modify the drivetrain with the installation of a crown gear and pinion of a different ratio that would have enabled the NEOPLAN to achieve a maximum speed of 120 km/h with engine rpm at 2300. Additionally, a dual-range governor that would have limited the maximum road speed to 100 km/h would have placed the engine in an operating range where it would no longer have been susceptible to valve failure because of sustained high RPM operation. Unfortunately, the modification was not completed because NEOPLAN could not source a crown gear and pinion to specification. Without this modification the powertrain is not expected to function satisfactorily in intercity operation.

Parts Cost Availability and Inventory Requirements: During the service demonstration, availability of parts and components was not a specific problem. Those components which did fail were supplied by North American distributors or were structural in nature and could be repaired by Voyageur. Where the parts required were of origin to NEOPLAN, their landed cost was very high (e.g., a replacement windshield for the NEOPLAN cost $1500 while the North American equivalent cost $154.).

It is Voyageur's opinion that should the NEOPLAN articulated bus be put into service, there would be a very significant problem with regards to maintaining a suitable stock of components given the relatively poor reliability of the equipment. This would require excessive inventory of high value components, a significant disadvantage for the European coaches.

3.2.2 Analysis of Repair Records

As only one articulated bus was involved in the service demonstration, insufficient data for statistical analysis on the frequency of repairs, O&M costs or down time expected from a fleet of articulated buses was compiled for statistical analysis. Furthermore, as a result of the low reliability of the NEOPLAN bus, any data obtained is probably not indicative of the true economics of articulated buses.

During the period December 4th, 1981 to December 31st, 1981 the NEOPLAN articulated bus operated on the service demonstration with no major failures. For this short time span, the Neoplan articulated bus experienced what might be termed "normal" scheduled and unscheduled maintenance similar to that which might be experienced by the MC-9 buses. The results of an analysis of the maintenance records during this period however clearly shows that even though the NEOPLAN bus did function without major failures, the actual maintenance and operating costs were three times higher than those experienced with the baseline MC-9 buses.

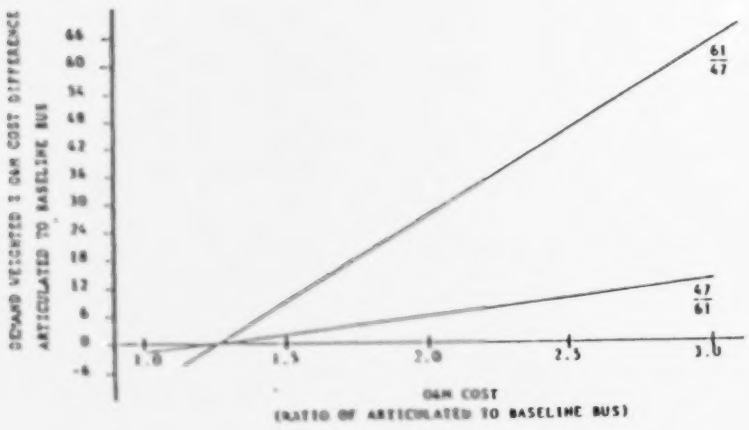
It was also found that the actual fuel consumption per thousand seat-kilometre (Table 3.2) compared closely with those experienced by the lower capacity baseline MC-9 buses. Thus, the higher capacity of the NEOPLAN bus did not result in any reduction in fuel costs per seat-kilometre.

TABLE 3.2: FUEL CONSUMPTION RATE COMPARISON

Bus Type	Seating Capacity	Average Trip Fuel Consumption (l/100)	Fuel per Thousand Seat-Km (l)
MC-9	47	46.5	9.9
Neoplan	61	61.1	10.0

Analyses of Voyageur O&M costs for conventional buses and the Neoplan articulated bus with typical passenger demands from the service demonstration have shown that the break-even O&M penalty is 25%, i.e., the O&M costs for the articulated bus cannot exceed by more than 25% that of the baseline MC-9 bus in Voyageur's operating environment and remain cost competitive. (Figure 3.1)

FIGURE 3.1: DEMAND WEIGHTED COSTS VS O&M COSTS
BASELINE MC-9 AND NEOPLAN ARTICULATED BUSES



3.3 STRUCTURAL FAILURE ANALYSIS

Following severe failure of a number of the main structural members of the rear section of the articulating joint in January 1982, the bus was removed from service.

Repairs and modifications to the structural members were carried out based on drawings supplied by NEOPLAN, with further adaptations designed by Voyageur personnel. Before a final decision on returning the bus to regular service was made, an analysis of the repairs and modifications was undertaken to determine whether the articulating joint was likely to fail again in service. This analysis was carried out in July, 1982.

The analysis included:

- an examination of the failed structural members which had been removed during the repair work,
- discussions with Voyageur personnel familiar with the failure, review of the suggested modification drawings provided by NEOPLAN,
- measurement of stress levels in the modified structural members under operating conditions,
- diagnosis of the probable cause of the failure, and
- an assessment of the suitability of the repairs and modifications carried out.

As shown in from Figure 3.2, the NEOPLAN bus is constructed in two sections with an articulating joint between them. Motive power is transferred to the ground via the tandem axles at the rear of the front section. Steering is accomplished in the normal manner by the front wheels, with an additional linkage to the extreme rear axle so that its wheels also steer. The articulating joint allows a limited amount of rotation about the vertical and transverse horizontal axes (yaw and pitch), but does not allow for any rotation about the longitudinal horizontal axis (roll).
The reason for this can be seen in Figure 3.3, which gives a stylized drawing of the main components of the articulating joint. The lower portion of a turntable, which allows yaw motion, is fixed to the front section of the bus. The upper half of this turntable has a large transverse beam with two bearings mounted on it. These bearings support transverse pins which are fixed to the rear section of the bus, thus allowing pitch motion. The pins are mounted at the forward ends of two cantilever support beams which project forward from the main frame of the rear bus section. The failures under investigation took place at the points where these two cantilever beams were jointed to the main vertical frame members of the rear bus section.

In the initial construction, (shown in Figure 3.4) the cantilever beams were butted against a transverse frame member and welded to it. Additional support was provided by adding gussetting underneath the beams to join them to veritical frame members. The cantilever beams themselves were hollow box sections. The transverse and vertical frame members were dual box sections. In Figure 3.4 which shows a view of the failure in the gusset area where attached to the vertical frame member the cantilever beam has been cut away. However, the photograph shows the small piece of square box cross section remaining at the point where it was welded to the transverse frame member. The twin box construction of the transverse frame member can also be seen. The sketch in Figure 3.5 provides further orientation to aid in understanding the design features.

In the modified design, the cantilever beams were strengthened by using a boxed-in wide flange section, and were extended to the rear, past the transverse frame member, in order to better transfer any loading to the frame. Also, angled lateral support beams were added. Figure 3.6 shows a side view of the right hand side of the modified articulating joint, with the rear bus section to the left, the right hand cantilever beam running across the middle of the picture (with its lateral support arm in the left foreground) and the turntable visible in the lower right corner.

Prior to actual testing, a number of calculations were performed to predict the stress levels likely to be found in the structural members under investigation, namely the two cantilevered support beams of the rear section of the articulating joint. To calculate the stress, the bus was first weighted and measured by section. This allowed for the calculation of the action and reaction forces at the pins located at the forward ends of the cantilever beams as shown in Figure 3.7.

FIGURE 3.2: NEOPLAN ARTICULATED BUS

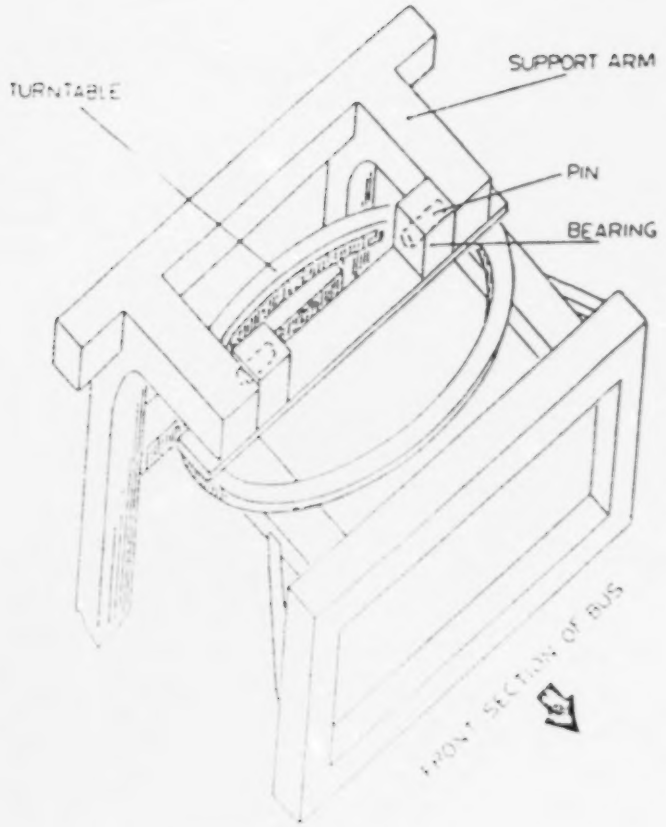


FIGURE 3.3
SCHEMATIC OF TURNTABLE

FIGURE 3.4
PHOTOGRAPH OF FAILED MEMBER

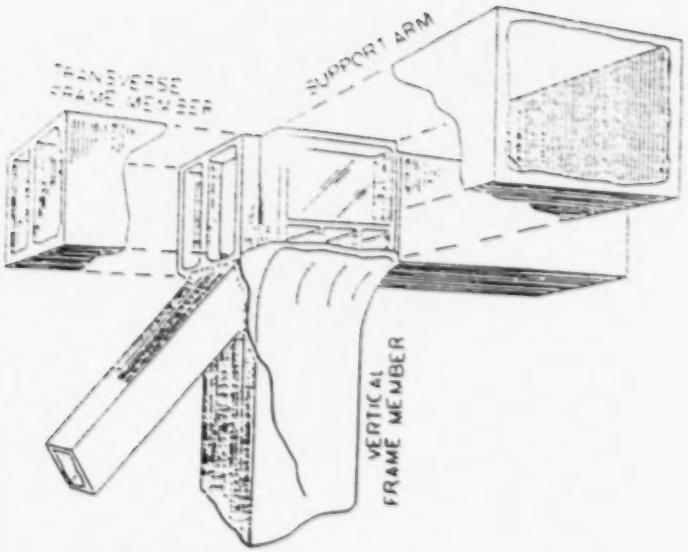


FIGURE 3.5
SCHEMATIC OF FAILED MEMBER

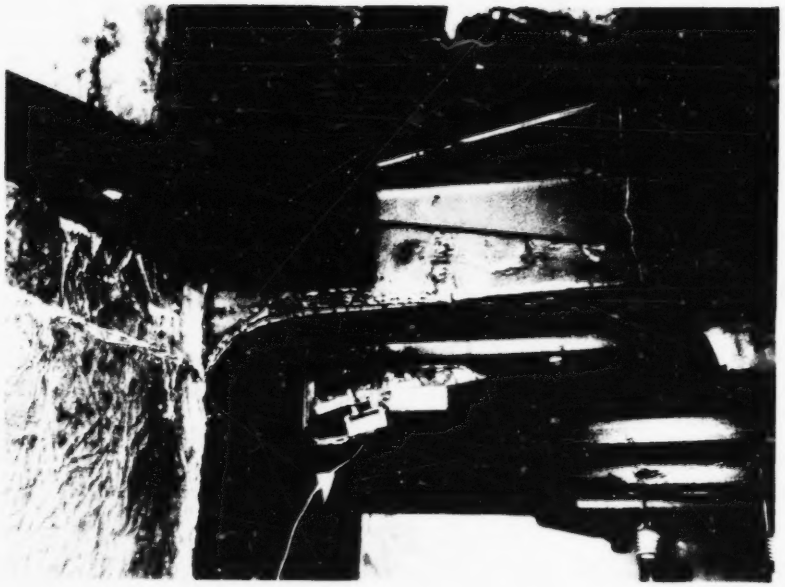
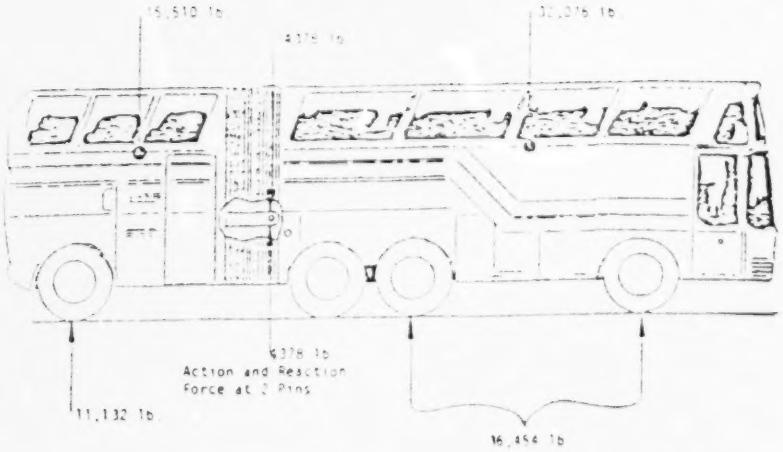
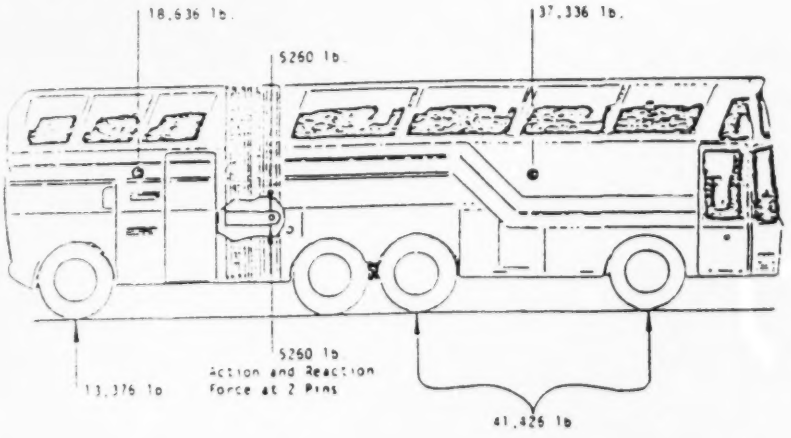


FIGURE 3.6
PHOTOGRAPH OF MODIFIED BEAM ARRANGEMENT



WITHOUT PASSENGERS



WITH PASSENGERS

FIGURE 3.7
MEASURED
STATIC LOADINGS ON BUS

Using this theoretical information a series of on the road stress tests was undertaken. The test results indicated that the failure of the structure members was the result of excessive cyclic stresses created by the design geometry of the structures. Further, the tests of the modifications indicated that stress levels had been reduced to limits which would not cause future failures in normal service.

3.4 PASSENGER/DRIVER ACCEPTANCE

Passengers using the articulated intercity bus during the service demonstration were informally surveyed (i.e., spot surveys). It was found that passenger acceptance was relatively high. The interior design and ergonometrics of the coach appeared to be satisfactory. Comfort in the tail section of the articulated bus, however, did not prove to be fully acceptable to passengers. The swaying motion in the tail section of the bus was unusual and unsettling to passengers.

A prime passenger concern was the speed of the coach. The NEOPLAN bus was continually late on arrivals in Montreal and Ottawa due to its limited maximum speed of 100 km/h. The 20-25 minute delay was a chronic complaint accentuated at times by later section buses overtaking the NEOPLAN en route.

Another major complaint was the very poor heating and ventilating system in the NEOPLAN bus. This problem occurred continuously throughout the service demonstration and appears to be specific to NEOPLAN's heating, ventilating and air-conditioning design. Any future heating, ventilating, air-conditioning system incorporated in an articulated bus must be to North American standards.

Driver complaints of the NEOPLAN bus concentrated on the drivers sitting position. As the driver sits relatively low in the NEOPLAN compared to conventional North American buses, this reduces the visibility for the driver and increases the possibility of a serious driver injury in the event of a frontal collision.

3.5 ECONOMIC VIABILITY

In view of the relatively short duration of the service demonstration, and the excessively low reliability of the NEOPLAN articulated bus, very little information can be drawn to assess the economic viability of articulated intercity coach operation in Canada. In particular, the results of the trial have shown that the NEOPLAN articulated intercity bus proved to be excessively expensive to operate and maintain and could not generate any economies of scale. The total effective time in which the articulated bus experienced no major mechanical or technical failures was in the first month's operation of the bus (December 4, 1981 through 31 December, 1981). During this period, it was found that normal maintenance and minor unscheduled maintenance resulted in a total maintenance cost three times higher than that of baseline MC-9 buses.

Fuel consumption during this period of operation was 61.1 L/100 km. By comparing the average fuel consumption of the NEOPLAN articulated bus carrying 61 passengers to a standard 47 seat MC9 coach operating during the same period (an average of five buses), the number of litres of fuel required per 1000 seat-kilometre for the NEOPLAN was 10.0 and for the MC9 standard 47 seat bus, 9.9. This information indicates that the operation of the NEOPLAN articulated bus penalized the carrier in terms of fuel consumption since it was originally expected that high capacity buses would generate lower fuel costs per seat-kilometre than conventional buses. The articulated bus did not meet this expectation.

It must be concluded that the NEOPLAN articulated bus was not operationally viable due to the high per passenger-kilometre operating and maintenance costs. No cost-savings or improved profitability can be expected to result from the use of the bus tested.

4.0 CONCLUDING REMARKS

In spite of all the shortcomings of the service demonstration, the delays, the difficulties, the mechanical failures of the NEOPLAN articulated bus, all participants judged that the service demonstration provided valuable insight into the characteristics of articulated intercity buses. Further, the circumstances surrounding the termination of the service demonstration resulted from specific mechanical and technical failures of the Neoplan articulated intercity bus and should not be generalized to totally reject the concept of larger buses.

The demonstration failed to stimulate significant interest in articulated intercity buses within the bus transportation community. The service demonstration clearly showed that the NEOPLAN articulated intercity bus was not acceptable for use in Canada and would not in its present configuration be procured by Canadian carriers. This however leaves room for the development of a Canadian articulated intercity bus incorporating better engineering design. Thus, because of the failure of this demonstration, the value of high capacity articulated intercity buses still remains unproven for the Canadian environment.

More definitive conclusions on the availability and maintainability of articulated bus maintenance must await further experience with articulated buses based on manufacture to Canadian specifications and built to more exacting standards.

From the findings and observations outlined in this report, several conclusions can be formulated with regard to further high capacity intercity bus developmental work:

- from the perspective of the potential carrier, there still remains no high capacity intercity bus available on the market today which will satisfy the latent demand for higher capacity buses;

- partially as a result of this project's failure, carriers will be demanding that higher capacity buses have demonstrated and proven better than average reliability before introduction into their fleets;

- foreign manufactured high capacity intercity buses are not expected to become commercially viable until their equipment are significantly improved for operation in the Canadian intercity environment;

- because the costs associated with the operation of a service demonstration of new equipment are very high, it is essential for a demonstrating carrier to realize that significant budget overruns can be expected;

- the joint venture of TDC working closely with the intercity bus carrier on the testing and demonstration of an articulated highway coach was successfully undertaken;

- the project demonstrated that a highdeck articulated intercity bus could be operated in service without substantial infrastructure and system changes;

- the NEOPLAN vehicle as specified for the demonstration suffered from numerous problems and did not prove to be a suitable vehicle for continuous operation in the Canadian environment;

- there were no passenger acceptance problems with the articulated bus;

- there were no significant driver acceptance problems with the articulated bus;

- manoeuverability and ride quality were similar to that of the standard coach and while the NEOPLAN had a superior suspension (less body sway), the standard coach has better traction;

- the NEOPLAN was substantially noisier than the standard bus, a problem resulting from the power train configuration specified for the coach;

- traction in snow and ice for the NEOPLAN was inferior to the standard bus as a result of the weight distribution inherent in most articulated designs, but both vehicles could start in fresh snow on level road at a depth of 25 cm;

- the transposition of European intercity bus design to a North American environment was a problem; a more extensive technical evaluation of the candidate equipment could have resulted in an improved specification prior to acquisition.

Although the articulated bus demonstration project was originally intended to validate the concept of high capacity intercity buses by demonstrating the expected cost savings and operational feasibility, the poor performance of the NEOPLAN articulated bus throughout the project invalidated any potential benefits that should have accrued from its higher capacity. Clearly, the failure to demonstrate the viability of high capacity intercity buses is caused directly by the poor performance of the NEOPLAN articulated bus and is not directly related to any unforeseen disadvantages or problems with the concept of higher capacity intercity buses.

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